REVIEW: MEADE'S HOT ETX REFRACTORS

Astronomy

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Peering into Black Holes

Which Came First: Stars, Galaxies, or Black Holes?

Astronomers Battle for Telescope Time

Southern Sky Treasures Revealed

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MEADE
LX90
MEADE LX90 EMC
MEADE

Now you can buy the telescope of a lifetime at a price you probably never thought possible.

The Meade 8" LX90, with diffraction-limited Meade optics in an Autostar™ computer-controlled telescope system, includes capabilities not available on other brands of 8" Schmidt-Cassegrains costing hundreds of dollars more. And, at $1695, the 8" LX90 — *with more than twice the light-gathering power* — is priced only a few hundred dollars more than competing *5"* Schmidt-Cassegrains!

Advanced capability incorporating the optical system and coatings of the 8" LX200, and with 5 arc-minute pointing precision in the GO TO mode. An instrument fully qualified for long-exposure CCD imaging and astrophotography as well as for other advanced photo-visual applications.

Special LX90 features include: (a) a die-cast-aluminum *double-tine* fork mount that rigidly supports the optical tube in all sky orientations; (b) *worm gears* of 4.9"-diameter on both telescope axes for smooth sidereal-rate tracking of celestial objects as well as precise guiding corrections during long-exposure imaging; (c) a rigid chromed-steel variable-height field tripod — *the same tripod provided with Meade LX200 models.*

Autostar Computer Controller: The LX90's *standard-equipment* Autostar controller connects to the telescope's control panel and permits an incredible array of telescope features:

- *Automatic GO TO capability* at 6.5°/sec on both axes, simultaneously, to 30,223 database objects, including:

  13,235 deep-sky objects — the complete Messier, Caldwell, IC, and NGC catalogs; 16,888 stars sorted by name and SAO catalog numbers; 8 major planets from Mercury to Pluto; the Moon; 26 asteroids; 15 comets; 50 Earth satellites; plus 200 memory locations for user-defined objects.
- *Automatic GO TO capability* to *any* object of known R.A. and Declination. Plus hundreds of special event menus, guided tours, utility functions, and telescope status options.
- *Nine selectable slew speeds:* 6.5°/sec, 3°/sec, and 1.5°/sec, as well as 128x, 64x, 16x, 8x, 2x, and 1x sidereal.
- *Control of the telescope* through your personal computer. (Requires optional #505 Connector Cable Set.)
- *Fast alignment of the telescope* in either equatorial or altazimuth modes using any of three alignment functions, including the Meade-proprietary Easy Align*.
- *Unlike the hand controllers* included with competing 5" and 8" SCT's, *Autostar is fully upgradeable over the Internet*: the observer can add the positions of new comets, update the positions of Earth satellites, even add new software as it becomes available.

Cordless Operation: The LX 90 is powered at 12 volts DC provided by (user-supplied) C-cell batteries. Alternately, the telescope may be powered from an automobile cigarette lighter plug or from a standard 115vAC home outlet, using optionally available power cords.

* Patent pending.

Meade 8" LX90 Schmidt-Cassegrain Telescope. Complete as shown:

$1695

SPECIFICATIONS: 8" LX90 — Each complete telescope includes 8" f/10 Schmidt-Cassegrain optical tube assembly with EMC super multi-coatings; double-tine fork mount with dual-axis 4.9" worm gears and control panel; electric slow-motion controls on both axes; Autostar hand controller with digital readout display, 9-speed drive controls on both axes, and GO TO controller; 30,223-object onboard celestial software library; internal battery port accepts 8 (user-supplied) C-cells (optional 25 ft. cords permit powering from either 12vDC auto cigarette lighter plug or from 115vAC home outlet); 8 x 50mm viewfinder; 1.25" diagonal prism; Series 4000 Super Plössl 26mm eyepiece; standard field tripod; operating instructions. **$1695.** Packing & shipping in the 48 states: $95.

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MEADE LX200

The largest-selling serious telescopes in the world are now available at the most affordable prices *ever!*

With their large object databases, fast slewing speeds, and uncanny pointing precision, Meade LX200's are recommended for those amateurs who intend an extensive program of CCD imaging, astrophotography, or deep-space observing. Compare a Meade LX200 feature-for-feature with competing single-tine-fork, spur-gear-driven, GO TO Schmidt-Cassegrains:

Superb Optics: With oversize primary mirrors for greater full-field illumination, LX200 diffraction-limited imaging capabilities are a legend in the industry; we regularly receive reports stating that optical performance approaches that of a fine *ED* apochromatic lens.

Automatic GO TO Capability: Competing 8" Schmidt-Cassegrains claim to place objects "somewhere in the field of view"; Meade LX200's place objects **dead-center** in the field of view, first time, every time, to a pointing precision of **2 arc-minutes or better,** or, with Meade exclusive High Precision Pointing, to a precision of **one arc-minute or better.** *Meade LX200's are the only commercial telescopes ever manufactured that automatically GO TO any input R.A. and Dec., or to any object in the onboard database, to these levels of precision.*

Database of 64,359 Objects, a database *more than three times larger* than competing GO TO telescopes.

Permanently-Programmable Smart Drive™ routinely achieves 5 arc-sec. periodic error, an observatory standard. Other brands of GO TO 8" SCT's decline to state their periodic error and do not offer any programmable error-corrector.

9-Speed Dual-Axis Electronics: Electronics that cover every contingency of telescope positioning — from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, plus 6 other dual-axis drive speeds in between.

Rigid LX200 Dual-Tine Fork Mountings with Dual 5.75" Worm Gears are the choice of advanced observers, CCD imagers, and astrophotographers for their most sensitive applications. Competing spur-gear-driven single-tine forks can not approach the strength, rigidity, and drive-rate precision built into every Meade LX200 mounting.

Full Long-Exposure Capability: Competing 8" GO TO telescopes describe their capability to take short-exposure "planetary and terrestrial photos," without reference to any long-exposure capabilities. Meade LX200's have been the instruments of choice in **thousands** of the most detailed long-exposure images ever taken by amateur astronomers.

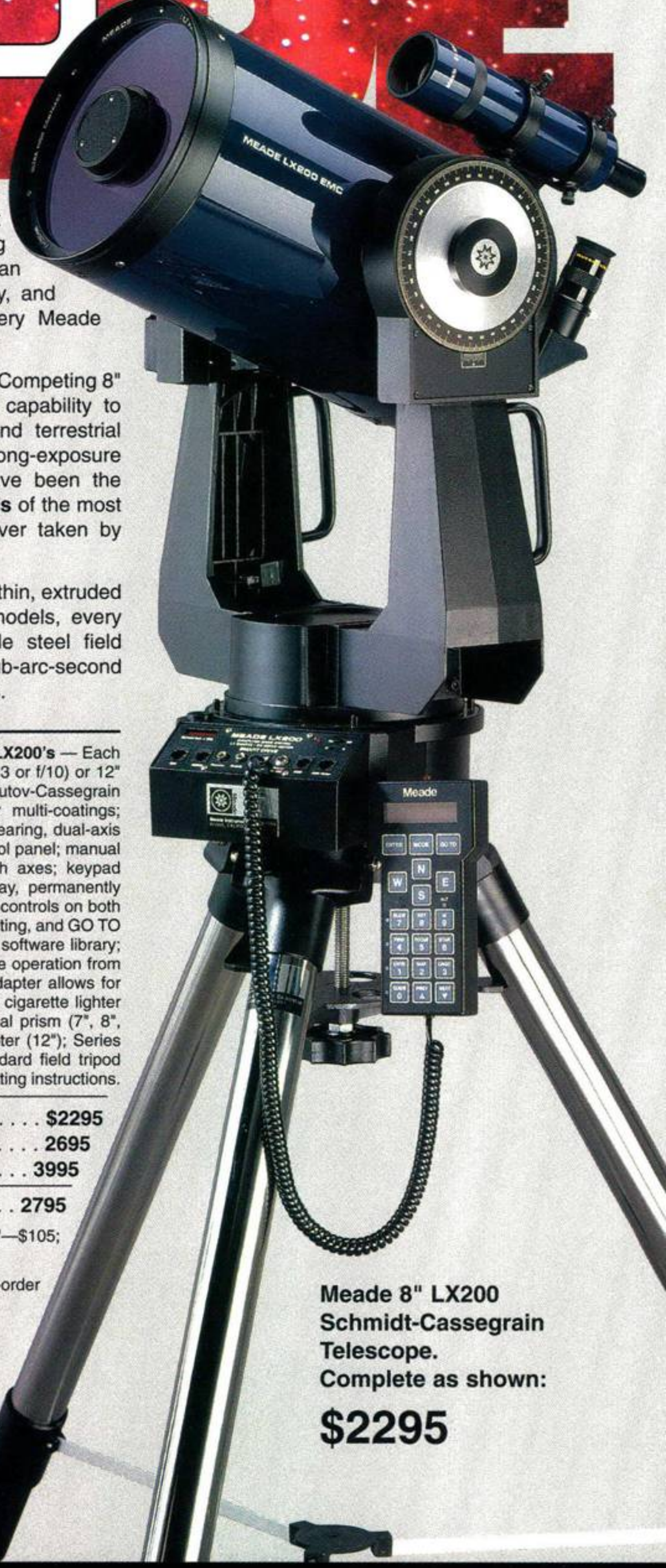
Strong Field Tripods: Unlike the thin, extruded aluminum tripods of competing models, every LX200 includes a fully adjustable steel field tripod perfectly suited to the sub-arc-second resolution of the telescope's optics.

SPECIFICATIONS: 7", 8", 10", and 12" LX200's — Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC (optional #1812 Electronic DC Adapter allows for field powering directly from an automobile cigarette lighter plug); 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.

8" LX200 Schmidt-Cassegrain	**$2295**
10" LX200 Schmidt-Cassegrain	**2695**
12" LX200 Schmidt-Cassegrain	**3995**
7" LX200 Maksutov-Cassegrain	**2795**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 7"—$125.

Prices shown are suggested U.S. mail-order retail prices.



Meade 8" LX200 Schmidt-Cassegrain Telescope. Complete as shown:

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February 2001 • Vol. 29, No. 2

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COVER ILLUSTRATION: Andrew C. Stewart

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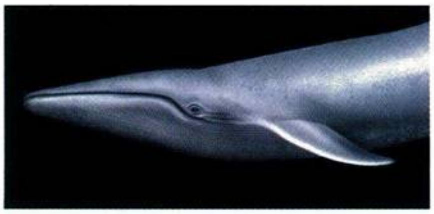

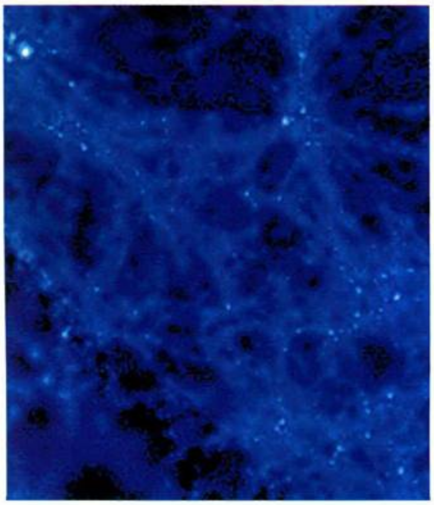

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Max-Planck Institute for Astronomy, Garching

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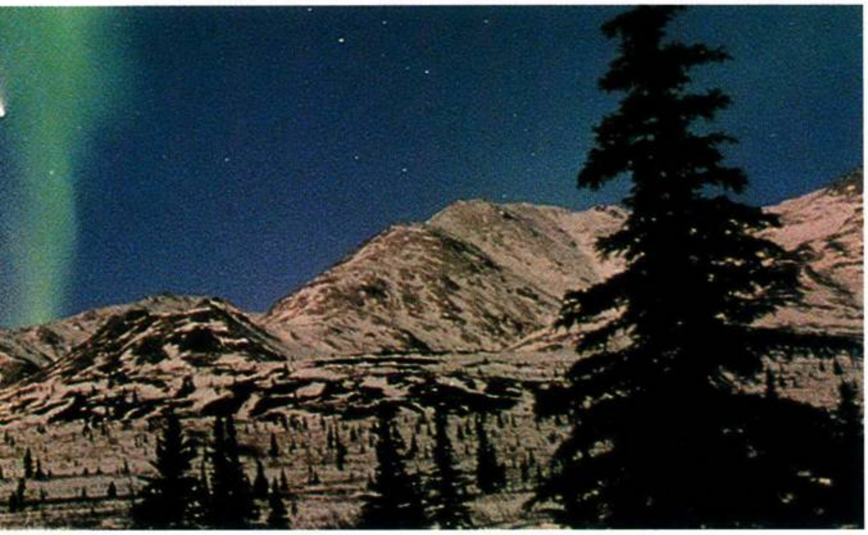

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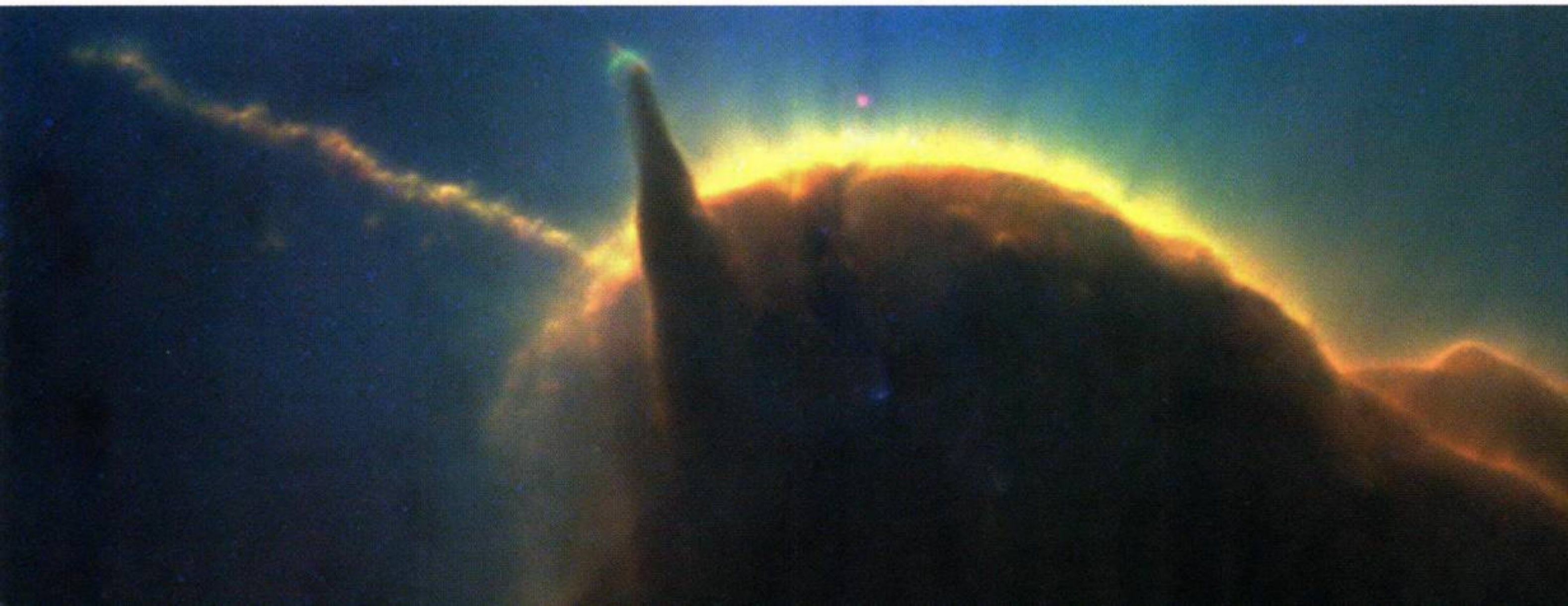

BEHIND THE SCENES

BY BONNIE BILYEU GORDON

Let's Go to Pluto

At a time when the economy of the United States is enjoying unprecedented success, it seems such an oddity to me that budgets get tighter and tighter, especially in science, the arts, and those school lunch programs. As a nation, we've never been quite so prosperous for quite so long a time. Why are we almost as tight as we are rich? Budget constraints have put a hold on NASA's first spacecraft to Pluto — the farthest flung of planets. Scientists argue that delaying the launch of the Pluto-Kuiper Express (PKE) could put off any mission to that region for between 7 and 255 years (more about the variance later).

NASA

I'm not opposed to saving some of the projected budget surplus for tax cuts. I could use a new roof on my house. Frankly, when there are things that the government needs to do, I'd just as soon add my tiny share of taxes to the need. I'd contribute my share to change the light bulbs on city streets so that skies might stay darker, or to build a system of animal migration trails across America so I don't have to look at roadkill victims every day as I commute to the office. I'd give up my cut to support NASA's trip to Pluto.

I'm not for casual spending, believe me. The president doesn't need another dessert chef, and I'm not supporting a renovation of the Congressional gymnasium, but it does seem to me that prosperity should bring generosity along with it.

For eight years NASA has seen nothing but budget cuts. One important project gets put on hold at the expense of another. We are told that the government can't maintain air for both an orbiter that will tell us what is on Europa and a first mission to Pluto. Both missions were in the works until September when PKE was delayed indefinitely. Space-science administrator Edward Weiler told members of Congress that projected costs for both missions had doubled and one needed to be bumped. This year — with Europa's promise of oceans — learning about Jupiter's moon has a higher priority than Pluto.

The decision is raising a small revolution among planetary scientists, space fans, and members of the Mars Society, who have launched a letter-writing campaign. Why all the fuss? Plenty of NASA missions get changed and even scrapped as the whims of Congress and the public change. This Pluto mission is more time-sensitive than most. If we delay the launch beyond its original target date of 2004, the spacecraft won't be able to take advantage of a gravity boost as it rings around Jupiter. The planetary choreography would then be wrong for gravity boosts for another 7 years. Even more delays could derive from a Pluto in deep freeze. The little planet is moving away from the sun on its elliptical orbit and will be distant enough to cool off and freeze up for 255 years, making a trip out there potentially useless.

So go ahead, spend my tax cut. Just give me what I want.

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Astronomy (ISSN 0091-6358, USPS 531-350) is published monthly by Kalmbach Publishing Co., 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187. Editorial phone: (262) 796-8776; advertising: (888) 558-1544; customer service & sales: 800-533-6644; outside the U.S. and Canada: 262-796-8776, ext. 421, Monday through Friday, 8:30 A.M. to 5 P.M. CT, Fax: (262) 796-1615; E-mail: customerservice@kalmbach.com. Please include your name, mailing address, and telephone number with any correspondence. Copyright © 2000 Kalmbach Publishing Co., all rights reserved. Material in this publication may not be reproduced in any form without permission. Periodicals postage paid at Waukesha, WI, and additional offices. Printed in the U.S.A. Allow 6 to 8 weeks for new subscriptions and address changes. Subscription rate: single copy: $4.50; 1 year $39.95, 2 years (24 issues) $74.95, 3 years (36 issues) $106.95; Canadian & foreign: 1 year $50, 2 years $95, 3 years $137. Payable in U.S. funds drawn on U.S. Banks. (Canadian price includes GST.) Expedited Delivery Service Surcharges: Domestic 1st Class $30 per year, Canadian air $30 per year, Foreign air, $60 per year. BN 12271 3209 RT. Canada Post Publication Agreement Number 545-775. Not responsible for unsolicited materials. POSTMASTER: Send address changes to *Astronomy*, 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187-1612.

8" LX10

8" LX10 DELUXE

The optical performance of a Meade 8" LX200 Schmidt-Cassegrain...for only *$995!*

8" LX10: For the serious amateur astronomer on a more limited budget, or for the more casual observer who nonetheless demands the very finest in optical performance, the Meade 8" LX10 satisfies every requirement. *Standard-equipment includes:*

Super-Multi-Coated Optical System: The *exact same* multi-coated 8" Schmidt-Cassegrain optical tube assembly as the more expensive Meade 8" LX200. **Series 4000 SP26mm eyepiece:** Complements the exquisite imaging of Meade 8" SC optics. **Equatorial Fork Mounting:** The relatively light weight, but very stable, LX10 fork mounting provides all of the rigidity required for sensitive high-power applications of the telescope, or for photographic or CCD imaging. **Cordless, DC-Powered Electronic Motor Drive:** With electronically-regulated DC servo motor for automatic *sidereal-rate* tracking; powered by four AA-size batteries that fit conveniently into the telescope's control panel; battery life is in excess of 50 hours. **Worm-Gear System:** The LX10's 5.75"-diameter worm gear produces extremely smooth, regular motion in R.A., with low periodic error — a periodic error that permits such advanced capabilities as long-exposure astrophotography or CCD imaging. **Hand Controller:** Essential for micro-guiding the telescope during long-exposure astrophotography, the LX10's pushbutton hand controller enables precise corrections in R.A. at 2x speed. With the optional electric Declination motor added to the telescope, the hand controller is functional at 2x speeds on both telescope axes.

SPECIFICATIONS: 8" Model LX10 — Includes 8" Schmidt-Cassegrain optical tube assembly with EMC super multi-coatings (D = 203mm; F = 2000mm, f/10); fork mount with setting circles, manual slow-motion controls, and locks on both axes; 5.75" LX worm gear reduction system; sidereal-rate electronically-regulated DC servo motor drive; 4-pushbutton hand controller for 2x speed corrections in R.A.; battery compartment accepting four (user-supplied) AA-size batteries (telescope may also be powered from an auto cigarette lighter plug, using optional 25 ft. cord); 6 x 30mm viewfinder; eyepiece-holder and diagonal prism (1.25"); SP26mm multi-coated eyepiece; standard equatorial wedge with elevation scale, fine elevation control, and 360° azimuth orientation capability; complete operating instructions. **$995.** (+ $65 packing & shipping in the 48 states)

8" LX10 Deluxe: At only $1149 the 8" LX10 Deluxe includes (a) the large-aperture Meade #544 8 x 50mm viewfinder (in place of the standard 6 x 30mm finder); (b) the LX10 Electric Declination Motor System, permitting dual-axis guiding corrections at 2x speed; and (c) Meade Epoch 2000 Jr. Sky Software with 10,000-object database — all at substantially lower cost than if the respective accessories were purchased separately.

SPECIFICATIONS: 8" Model LX10 Deluxe — Identical in all specifications to 8" Model LX10, above, but with Electric Declination Motor System provided as standard equipment, permitting dual-axis corrections at 2x speed; Meade #544 8 x 50mm achromatic viewfinder in place of 6 x 30mm viewfinder; and Meade Epoch 2000 Jr. Sky Software with 10,000-object database.
$1149. (+ $65 packing & shipping in the 48 states)

Field Tripod for LX10 or LX10 Deluxe	**195.**
Electric Declination Motor System for LX10	**95.**
#2014 Magellan I Telescope Computer System for LX10 or LX10 Deluxe, with 12,218-object database	**375.**

Prices shown are suggested U.S. mail-order prices.
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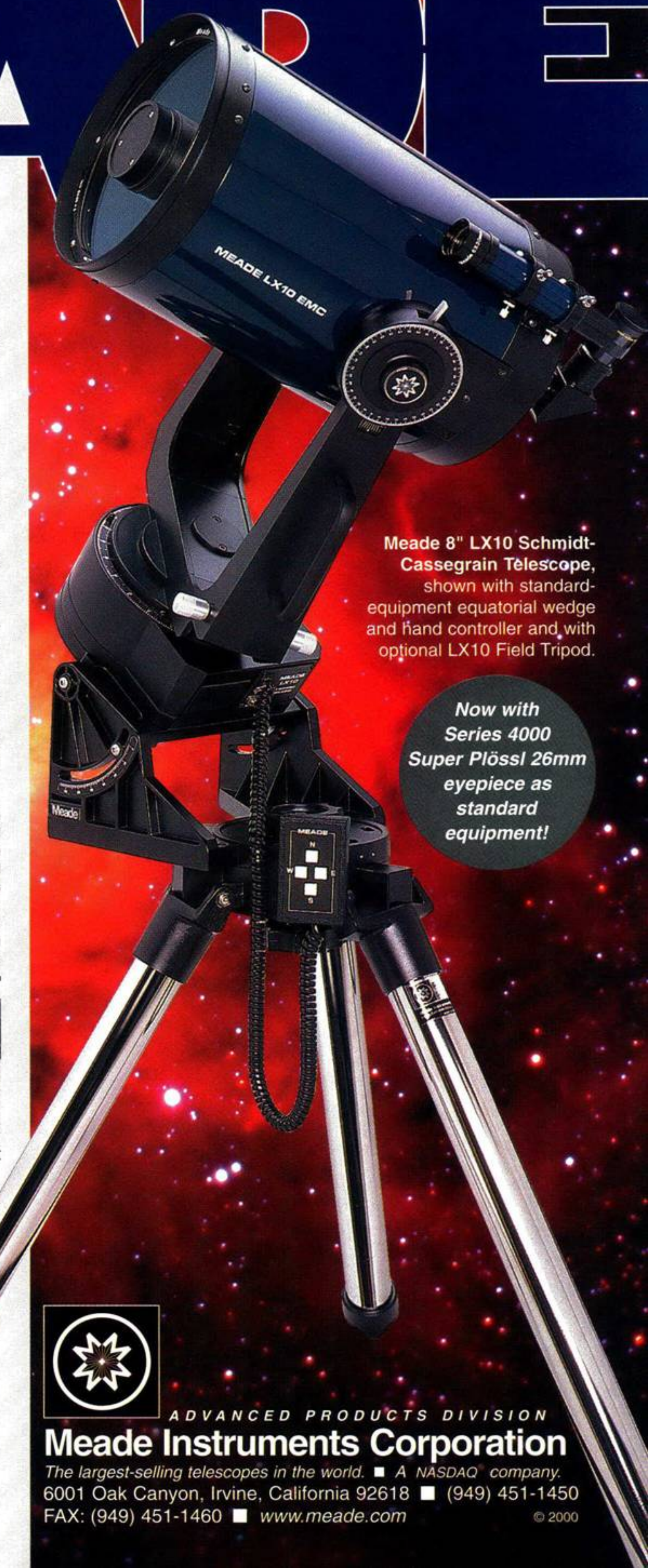

Meade 8" LX10 Schmidt-Cassegrain Telescope, shown with standard-equipment equatorial wedge and hand controller and with optional LX10 Field Tripod.

Now with Series 4000 Super Plössl 26mm eyepiece as standard equipment!

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MEADE ETX-60AT • ETX-70AT

New!

Now you can join the ETX revolution for as little as $299, complete!

Let Meade high-resolution ETX optics and standard-equipment Autostar controller take you on an automated guided tour of the Solar System, the Galaxy, and beyond. Now even the most novice amateur astronomer can locate and explore the planets, asteroids, and comets, as well as nebulae, star clusters, galaxies, and hundreds of other deep-space objects, at the push of a button.

Fork Mount with Dual-Axis Drive System: In conjunction with the Autostar hand controller, precision worm gear systems on each axis permit smooth pushbutton motions of the telescope, as well as sidereal-rate tracking in the altazimuth mode.

Standard-Equipment #494 Autostar™ Controller: The #494 Autostar includes most of the same features as the more advanced #497 Autostar available for larger Meade ETX models *(facing page).*

- **Automatic dual-axis GO TO function at 4.5°/sec.** to any of more than 1450 database objects, including the complete Messier and Caldwell deep-space object catalogs, the major planets from Mercury to Neptune, 26 asteroids, 15 periodic comets, and more.
- **Select any of Autostar's** database objects, or any object of known R.A. and Dec, press ***GO TO*** and the telescope automatically slews to the object, placing it in the telescopic field of view.
- **Digital readouts** of telescope position, continuously in R.A. and Dec.
- **9-speed Dual-Axis Operation:** Pushbutton control of the telescope on both axes, simultaneously, at any speed from 2x sidereal to 4.5°/sec., plus sidereal-rate tracking.

High-Resolution Achromatic Objective Lenses: ETX 60mm and 70mm models include multi-coated, air-spaced achromatic lenses of exclusive Meade design; each lens yields razor-sharp images of astronomical and terrestrial subjects.

Flip-Mirror System: Flip the internal optical flat mirror "up" for 90° observing; flip the mirror "down" for terrestrial observing with the optional #933 45° Erecting Prism or for photography with the optional #64ST Photo Adapter.

Cordless Operation: The dual-axis drive of Meade ETX-60AT and ETX-70AT models operates for over 20 hours in the field from six AA-size (user-supplied) batteries which store neatly inside the drive base.

Solar System: Saturn
Guided Tour Tonight's Best
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MEADE
COMPUTER CONTROL

ETX-70AT: $349, complete with #494 Autostar Controller.

ETX-60AT: $299, complete with #494 Autostar Controller

SPECIFICATIONS: ETX-60AT and ETX-70AT Astro Telescopes — Each includes achromatic refractor optical tube assembly (D = 60mm, F = 350mm, f/5.8 *or* D = 70mm, F = 350mm, f/5) with multi-layer optical coatings; internal flip-mirror system for either straight-through or 90° observing position; fork mount with electric slow-motion controls, setting circles, and locks on both axes; electronic control panel; 9-speed (2x sidereal through 4.5°/sec.) dual-axis motor drive system with #494 Autostar computer controller; sidereal-rate tracking; internal battery compartment accepting six (user-supplied) AA-size batteries; MA9mm (39X) and MA25mm (14X) multi-coated eyepieces; operating instructions. **ETX-60AT — $299** (+$10 packing & shipping in the 48 states); **ETX-70AT — $349** (+$10 P & S).

OPTIONAL SYSTEMS FOR MEADE ETX TELESCOPES*

#882 Standard Field Tripod (60, 70)	$99.00
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#64ST Photo Adapter (60, 70)	19.95
#497 Autostar Computer Controller (90, 125)	149.00
#880 Equatorial Table Tripod (90)	29.95
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#774 Hard Carry Case (90)	99.95
#775 Hard Carry Case (125)	149.95
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see also the Meade accessory ad in this issue.

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with Electronic
Controller

ETX-125EC:
$895,
complete with
Electronic
Controller

Two advanced apertures:
ETX-90EC — $595
ETX-125EC — $895

Meade® 3.5" and 5" ETX® models include the very latest in microprocessor-controlled capability:

Fork Mount with Dual-Axis Drive System: Each with high-torque DC motors on both telescope axes, permitting electronic operation from the standard-equipment plug-in hand controller.

Pushbutton Electronic Hand Controller: Use at any of four dual-axis speeds: 8x for image centering at high power; 32x for image centering at lower power or for pushbutton object-tracking in the altazimuth mode; 0.75°/sec for image centering in the viewfinder or for terrestrial tracking; 5°/sec for fast slewing across the sky.

Maksutov-Cassegrain Optical Systems: Manufactured at the Meade Irvine, facility, ETX diffraction-limited optics produce images so high in contrast and resolution that ETX telescopes often outperform other telescopes of larger apertures.

Flip-Mirror System: Flip the internal optical flat mirror "up" for 90° observing; flip the mirror "down" for terrestrial observing with the optional #932 45° Erecting Prism or for photography with the optional #64 Photo Adapter.

Cordless Operation: The dual-axis drive system operates for more than 40 hours from eight (user-supplied) AA batteries which store neatly inside the drive base.

Optional #497 Autostar™ Capability: Plug in the optional Meade #497 Autostar computer controller for LX200-type operation, including:

- **Automatic dual-axis GO TO function at 5°/sec** to any of more than 14,000 database objects, including deep-space objects (galaxies, diffuse nebulae, planetary nebulae, star clusters); the 8 major planets from Mercury to Pluto; 26 of the brightest asteroids; 15 periodic comets; and more.
- Select any of Autostar's database objects, or any object of known R.A. and Dec, press ***GO TO*** and the telescope automatically slews to the object, placing it in the telescopic field.
- **Digital readouts** of telescope position, continuously in R.A. and Dec.
- **9-Speed Dual-Axis Operation:** Pushbutton control of the telescope on both axes, simultaneously, at any speed from 2x sidereal to 5°/sec., plus sidereal-rate tracking.

ETX AUTOSTAR
MEADE
ENTER
MODE
GO TO

SPECIFICATIONS: ETX 90EC and ETX-125EC Astro Telescopes — Each includes Maksutov-Cassegrain optical tube assembly (D = 90mm, F = 1250mm, f/13.8 *or* D = 127mm, F = 1900mm, f/15) with EMC super multi-coatings; internal flip-mirror system for either straight-through or 90° observing position; fork mount with electric slow-motion controls, setting circles and locks on both axes; electronic control panel; 4-speed (8x, 32x, 0.75°/sec, 5°/sec) dual-axis motor drive system with hand controller; sidereal-rate tracking in equatorial mode with optional table tripod or deluxe field tripod; internal battery compartment accepting eight (user-supplied) AA-size batteries; 8 x 21mm erect-image (ETX-90EC) *or* 8 x 25mm right-angle (ETX-125EC) viewfinder; Series 4000 Super Plössl 26mm eyepiece (1.25"); instructions. **ETX-90EC — $595** (+ $20 packing & shipping in the 48 states); **ETX-125EC — $895** (+ $30 P & S).

AUTHORIZED U.S. AND CANADA MAIL-ORDER DEALERS

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 925-447-9570.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

POCONO MOUNTAIN OPTICS, Moscow, PA.
Orders: 800-569-4323; Info.: 570-842-1500.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 847-367-4600.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

6001 Oak Canyon, Irvine, CA 92618. (949) 451-1450. FAX: (949) 451-1460. www.meade.com

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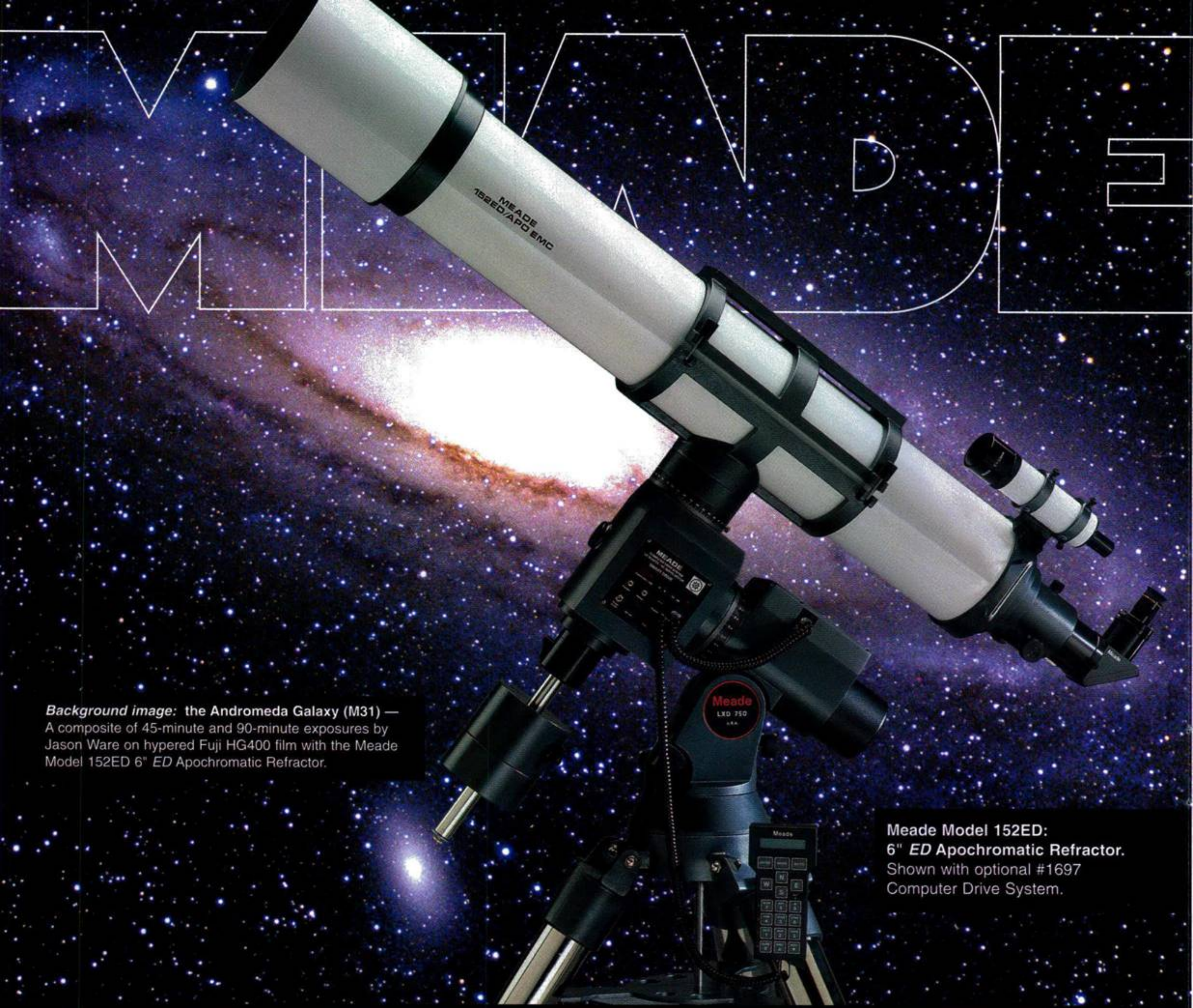

Background image: **the Andromeda Galaxy (M31) —** A composite of 45-minute and 90-minute exposures by Jason Ware on hypered Fuji HG400 film with the Meade Model 152ED 6" *ED* Apochromatic Refractor.

Meade Model 152ED:
6" *ED* Apochromatic Refractor.
Shown with optional #1697 Computer Drive System.

ED APOCHROMATIC REFRACTORS

"The color correction and optics of my Meade 6" ED/APO are superb—the highest levels of definition, contrast, and resolution of any telescope near its aperture range that I have used in 44 years of observing. The Moon is awesome, incredibly detailed, with features taking on almost a 3-dimensional appearance. In good seeing the belts of Jupiter resolve into fine, delicate features; colors of the belts are faithful, dramatic, and easy to observe. Sketching the finer features of Jupiter's surface is a pleasure with this first-class instrument. When Saturn's rings are opened up, minor ring divisions are well-defined. The colors of Mars are beautiful and faithful, with good detail visible when the planet is favorably placed; many clouds are easily followed, and the polar caps are well-defined. Deep-space objects are viewed in high contrast. The telescope passes all test double stars easily. The LXD 750 equatorial mounting is excellent, extremely rigid and smooth; the computer drive puts objects in the center of the field. I can't praise the telescope enough. A magnificent instrument." **— Phillip W. Budine, Past Executive Director and Jupiter Recorder, Association of Lunar and Planetary Observers.**

Fortunate indeed is the observer with a Meade *ED* Apochromatic Refractor at his or her disposal, for these are professional-class instruments capable of serious research. Use the massive Meade **LXD 650** (4", 5") or **LXD 750** (6", 7") equatorial mounts in conjunction with the optional **#1697 Computer Drive System** to slew the telescope across the sky and computer-point the instrument, automatically, *to a precision of one arc-minute,* or actuate any of 9 pushbutton-controlled drive speeds (from 2x photoguide to 8°/sec. fast-slew) on both axes. More than 40 Meade optional accessories are available to suit virtually any observing, photographic, or CCD imaging requirement.

Supplied complete per catalog specifications:

4" f/9 Model 102ED	**$2795.**
5" f/9 Model 127ED	**3295.**
6" f/9 Model 152ED	**4995.**
7" f/9 Model 178ED	**5995.**
#1697 Computer Drive System	**795.**

Packing and shipping in the 48 states: 4"—$105; 5"—$125; 6"—$185; 7"—$215. Prices shown are suggested U.S. National mail-order retail prices.

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STARFINDER™ EQUATORIAL NEWTONIANS

Meade® Starfinder 8" Equatorial with Motor Drive... *now only* ***$599!***

Complete with giant rack-and-pinion focuser for 1.25" and 2" eyepieces, 6 x 30mm viewfinder, Super Plössl 26mm eyepiece, and premium-grade Pyrex® optical system.

Precision, heavy-duty equatorial mount with DC-powered drive system for fully automatic tracking.

Shown with optional #2011 Magellan I Computer System.

Professional-Grade Optical System: Hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

Accessories and Components: Premium-grade multi-coated SP26mm eyepiece (1.25"); 6 x 30mm viewfinder with wide 7° field; strong, durable, spiral-wound optical tube with attractive white finish.

Precision Equatorial Mount: Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

Battery-Powered Cordless Drive System: For fully automatic tracking of celestial objects. Operates over 50 hours from 6 (user-supplied) AA-batteries or from 12v. auto cigarette lighter plug, using optional 25 ft. cord.

2" Giant Focuser: Meade #77 giant rack-and-pinion focuser is included as standard equipment, with eyepiece-holders for both 1.25" and 2" eyepieces.

Starfinder Equatorial 16: Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6" dia. pier, and 6 x AA-size battery-powered worm gear drive; 8 x 50mm viewfinder; #77 giant focuser.

Magellan I Telescope Computer System: Use the Magellan I computer to manually slew the telescope quickly to any of 12,218 database objects, or to any object of known R.A. and Dec. Specifications and object database are identical to Magellan I for Starfinder Dobsonians *(see facing page).*

#2011: for Meade Starfinder Equatorial 6", 8", or 10" . . . . . $295.
#2012: for Meade Starfinder Equatorial 16". . . . . 295.

Magellan II Computer-Corrector: Plug the Magellan II into the control panel of your Meade Starfinder Equatorial and you have all the capabilities of the Magellan I, above, including 12,218-object database, *plus* a 4-speed (2x, 8x, 16x, 32x), dual-axis, drive corrector/microslewing system.

#2018: for Starfinder Equatorial 6", 8", 10" . . . . 495.
#2019: for Starfinder Equatorial 16" . . . . 595.

Packing & shipping in the 48 states: Magellan I – $15, Magellan II – $20.

Special Eyepiece Offer! At the time you order any Meade Starfinder Equatorial telescope, you can buy a Meade Series 4000 Super Plössl 9.7mm eyepiece ***for only $29.95!*** *Purchased separately, the SP9.7mm eyepiece sells for $79.95.*

Meade Starfinder Equatorial Telescopes

6" f/8	**$499**	**10" f/4.5**	**699**
8" f/6	**599**	**16" f/4.5**	**2695**

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$65; 8"—$75; 10"—$90; 16"—$55 packing, shipped truck freight collect.

To Order any Starfinder model: contact your authorized Meade Advanced Products Dealer. Prices shown are suggested U.S.A. mail-order retail prices.

New 120-page 2000 Meade General Catalog!

Write, call, or fax Meade Instruments for your free copy.

ADVANCED PRODUCTS DIVISION
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MEADE RESEARCH-GRADE ACCESSORIES

Series 4000™ Super Plössls
52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm each: **$79.95** (4.54)

32mm (52°); **40mm** (44°) each: **99.95** (5.26)

56mm (52°; 2") **199.95** (7.02)

Series 4000™ Ultra Wide Angle
84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (5.26); **6.7mm: 199.95** (5.26); **8.8mm** (1.25"/2"): **239.95** (7.02); **14mm** (1.25"/2"): **299.95** (7.02)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

$149.95 (6.14)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (5.26)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue

each **$14.95** (2.73)

Set #1–4 filters: #12, #23A, #58, #80A **49.95** (4.54)

Set #2–4 filters: #11, #25A, #47, #82A **49.95** (4.54)

Set #3–4 filters: #8, #21, #38A, #56 **49.95** (4.54)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.73)

Series 4000™ 2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

$79.95 (5.26)

Series 4000™ Super Wide Angle
67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (4.54); **18mm: 149.95** (4.54); **24.5mm: 179.95** (5.26); **32mm** (2"): **239.95** (7.02); **40mm** (2"): **299.95** (7.02)

Series 3000™ Plössls
50° field; multi-coated

Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Focal lengths from 5mm through 25mm are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. All eyepieces are fitted with fold-down rubber eyecups for comfortable observing. The PL40mm *(far right in photo)*, an excellent complement to any ocular set, produces spectacular low-power, wide fields, ideal for scanning the Milky Way. Manufactured exclusively to Meade optical designs, Series 3000 Plössls yield fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)

5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.86); **40mm** (44° field): **$79.95** (3.86)

#911B
#910B
#908B

#911N
#910N
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia. **79.95** (4.54)

#910B–Threads into 2" eyepieces, 44mm dia. **119.95** (5.26)

#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. **99.95** (5.26)

#908N–Threads into 1.25" eyepieces, 26mm dia. **89.95** (4.54)

#910N–Threads into 2" eyepieces, 44mm dia. **129.95** (5.26)

#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. **119.95** (5.26)

#911X
#910X
#908X

Series 4000 Oxygen-III Filters Observe diffuse emission and planetary nebulae as you never thought possible! Exclusive Meade *60-layer* interference coating technology isolates the 496nm and 501nm O-III lines to tremendously enhance observable nebular structural detail in all telescopes.

#908X–Threads into 1.25" eyepieces, 26mm dia. **99.95** (4.54)

#910X–Threads into 2" eyepieces, 44mm dia. **159.95** (5.26)

#911X–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. **149.95** (5.26)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

f/6.3 FOCAL REDUCER/FIELD FL

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture. **$129.95** (5.26)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (4.54)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (5.26)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated.

$47.95 (4.54)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

$59.95 (4.54)

2" *Diagonal Mirror*

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

#929 or **#930,** each: **$99.95** (6.85)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

$42.95 (3.86)

Electric Focusers for SCT's

For extremely smooth microfocusing of the image. Does not affect use of the manual coarse-focus knob.

#1206 Electric Focuser: Plugs into control panel of Meade 8", 10", 12" LX200 models and operates from LX200 hand controller. **$149.95** (7.48)

#1205 Electric Focuser: For **all** other Meade 8", 10", 12" SCT models; includes separate hand controller; accepts one self-contained (user-supplied) 9v. battery.

$169.95 (7.88)

#777 Off-Axis Guider for SCT's

Internal prism diverts light for monitoring telescopic image during long-exposure astrophotography. Threads to any Meade or Celestron rear cell. Use with illuminated reticle eyepiece and T-Mount for your 35mm camera.

$79.95 (6.85)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (4.54)

MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle; rubber eyecup. Wireless red LED illuminator and variable brightness control. 1.25". **Batteries included.**

$99.95 (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (5.26)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": $27.95; **1.25": $29.95** (3.86)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (3.86)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

$39.95 (3.86)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (3.86)

CCD-Photo-Visual Flip-Mirror Systems

An essential accessory for imaging with ***any*** brand of CCD imager or for astrophotography with a 35mm camera. Flip mirror "down" to center the image while viewing with an eyepiece at 90°; flip mirror "up" to pass light on to CCD chip or 35mm camera film plane. Each unit includes: precision optical-flat Pyrex® mirror; 2-axis mirror-adjustment screws and locks for precise image centering; extra-fine helicoid focusing of the eyepiece; extension tubes for attaching either 35mm camera (using T-Mount) or CCD imager (using either T-threads or 1.25" barrel). Threads to rear cells of all Schmidt-Cassegrain telescopes; may remain on telescope and used in place of diagonal prism for visual observing as well.

"Over the past 10 years I have used all manner of flip-mirrors. The Meade Flip-Mirror Systems are absolutely the best—rock solid, high-precision, beautifully manufactured; they virtually eliminate all flexture between the CCD and telescope." — Jack Newton

#644 Flip-Mirror System: Accepts any 1.25" eyepiece. Mirror clear aperture: 22mm. Use with CCD's up to Pictor 416XT or ST-7, or smaller; or visual observing with 1.25" eyepieces. **$149.95** (7.02)

#647 Flip-Mirror System: Accepts either 1.25" or 2" eyepieces. Mirror clear aperture: 40mm. Recommended for full-field 35mm astrophotography or with CCD's of any size, including all Meade Pictor Series through 1616XT, as well as ST-4 through ST-8; or for visual applications with 1.25" or 2" eyepieces. **249.95** (8.49)

#157 1.25" Adapter: Permits use of either Flip-Mirror on telescopes with 1.25" eyepiece-holders. (Requires approx. 2" additional focus travel with #644, 3" with #647.) **15.00** (3.86)

NEW!
MEADE
MEADE
PICTOR

#644
MEADE
FLIP-MIRROR SYSTEM

#647
MEADE
FLIP-MIRROR SYSTEM

Epoch 2000® Sky Software

The most powerful astronomical software ever made available can now be yours for only $149!

Epoch 2000sk *(upper display at left)*: Now you can use the most advanced, most precise full-color sky software ever created, to zoom-in on telescopic fields **smaller than one arc second!** With star positions displayed as precisely as **0.01 arc second,** the Trapezium in Orion is no longer shown as a single point, as in other software, **but as four precisely oriented starpoints, just as they appear in the telescope.** No longer do you need to guess the R.A. and Dec. of an object located away from the field center, as in other programs: Epoch 2000sk dynamically reads out the R.A. and Dec. of the cursor position anywhere in the field **and updates R.A. and Dec. instantaneously as the cursor is moved about the field.** Meade LX200 owners can use Epoch 2000sk for remote auto-centering of objects in the telescopic field **to a precision of 30 arc seconds,** routinely!

Print professional-quality star charts in either black-and-white or color, at any zoom setting or sky scale between 180° and one arc second, with your own customized borders, headers, footers, margins, fonts, colors, and grids.

Epoch 2000ip Image Processing Software *(lower display at left)*: Epoch 2000ip makes it easy to enhance and analyze your CCD images with the same sophisticated techniques used by professional astronomers to uncover hidden structure in a spiral galaxy or obscure detail on the surface of a planet. This powerful software includes virtually every technique available for image enhancement. Techniques that bring out detail totally invisible in your original image, transforming it from the ordinary to the spectacular.

EPOCH 2000sk Sky Software: 281,000 objects supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 . . . . **$149**

EPOCH 2000sk-CD Sky Software: 19 million objects, including the complete Hubble Guide Star Catalog; supplied on CD-ROM **179**

LX200 Interface Cable: for Meade LX200 operation by Epoch 2000sk **25**

EPOCH 2000ip Image Processing Software: Supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 . . . . **$199**

4000 f/3.3 CCD FOCAL REDUCER

Series 4000™ f/3.3 CCD Focal Reducer/Field Flattener

NEW!

Revolutionary 3-element Meade design permits ultrafast CCD imaging with **increased** edge-of-field resolution and color correction! Reduces CCD exposure times by up to 80%. Threads on to the rear cell of any Meade or Celestron Schmidt-Cassegrain. Converts f/10 Schmidt-Cassegrain telescopes to **f/3.3** and f/6.3 SCT's to **f/2.** Variable T-Adapter (included) allows range of f/ratios between f/3 and f/5 on f/10 SCT's and between f/1.9 and f/3.2 on f/6.3 SCT's. Use with CCD imagers of any brand and chip dimensions. Not for visual or photographic applications. Multi-coated; 41mm clear aperture. **$149.95** (5.26)

Plössl 25mm Illuminated Reticle CCD Framing Ocular

NEW!
MEADE
PLÖSSL
CCD FRAMING

Displays rectangular frames of all popular CCD chip sizes, including all Meade Pictor models and ST-4 through ST-8. Shows precisely the image size and orientation that appear on CCD chip. Insert directly into telescope eyepiece-holder, or use with Flip-Mirror *(above)*. Includes 4-element coated Plössl optics; lockable spacer ring to fix focus position; rubber eyecup; variable LED illumination control; batteries. 1.25". **$129.95** (4.54)

#825 8 x 25mm Right-Angle Viewfinder for ETX-90

Permits comfortable right-angle viewing. Replaces standard-equipment finder on 90mm ETX models, using the same bracket. Wide-angle, achromatic, coated optics; actual field 7.5°. Precise helicoid focusing. **$49.95** (4.26)

#64 T-Adapter for ETX®

Threads to the photo port of all ETX-90 and ETX-125 models. Rigidly couples any 35mm camera with removable lens to the telescope for lunar, planetary, or terrestrial photography. Includes extension tube for longer effective focal length, if desired. Use with T-Mount for your 35mm camera. **$34.95** (3.86)

MA12mm Illuminated Reticle Astrometric Eyepiece

NEW!
MEADE MA
ASTROMETRIC
ILLUMINATED

A high-precision eyepiece for a wide range of astronomical measurements. Includes four red-illuminated, laser-etched scales for measuring double star angular separations, position angles, planetary diameters, and lunar crater diameters, and for long-exposure photo-guiding. Modified Achromatic 3-element coated optics; diopter adjustment; rubber eyecup; variable LED illumination control; batteries. 1.25". **$119.95** (4.26)

Series 4000™ 8mm – 24mm Zoom Eyepiece

NEW!

The finest zoom eyepiece available. High-resolution 7-element multi-coated optics, with 55° field at 8mm. Graduated scale in 1mm units indicates exact focal length in use. High-eyepoint yields comfortable observing even with eyeglasses. Internal zoom lenses move on the smoothest, most precisely-machined tracks yet developed for zoom optics. Performance is fully consistent with the finest fixed-focal length eyepieces. Threaded for filters; rubber eyecup; 1.25". **$219.95** (6.38)

ETX® Hard Carrying Cases

For secure storage or travel with your ETX. Thick-wall construction and die-cut foam lining. Accepts telescope, plus optional eyepieces, erecting prism, table tripod, hand controller, *etc.* Includes two steel latches with key.

#774 Case for ETX-90 models: **99.95** (8.58)

#775 for ETX-125EC: **149.95** (13.38)

#932 45° Erecting Prism for ETX®

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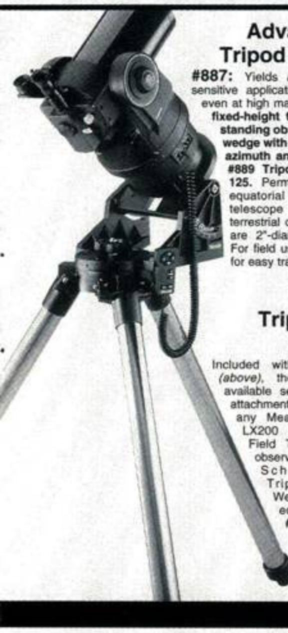

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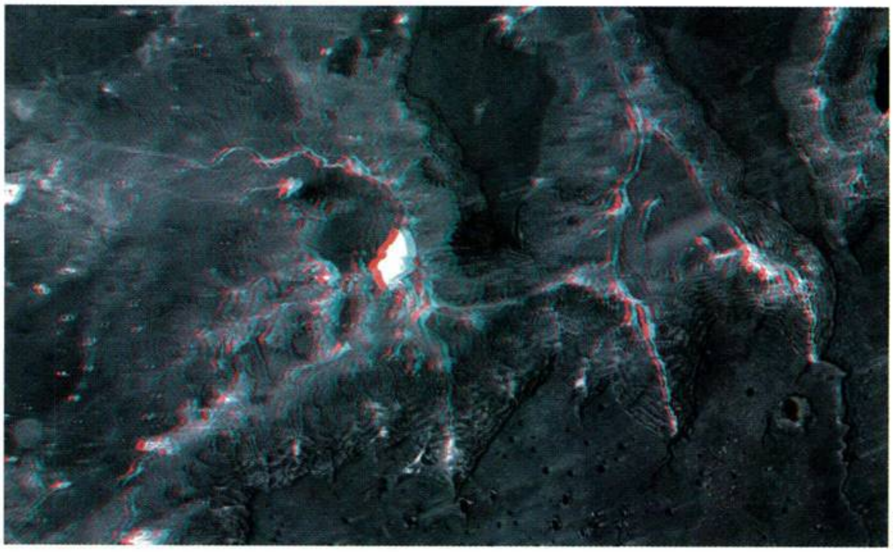
Varied Career Paths

I am concerned by some of *Astronomy*'s advice and articles (November 2000) relevant to careers in astronomy. These articles lead readers to believe that a graduate degree in astrophysics and experience working with telescopes is necessary. However, astrophysicists make up only a tiny fraction of the people who are considered astronomers.

For example, my colleagues with degrees in mineralogy and chemistry use the world's most powerful microscopes and mass spectrometers to study the origin of the solar system from clues locked in meteorites. Others with degrees in geology and volcanology use images from spacecraft to study the evolution of the surface of Mars and other planets. I also know biologists who seek to discover if life exists on Mars. These people may call themselves cosmochemists, planetary geologists, and astrobiologists, but overall these space scientists are considered astronomers.

An advanced academic degree is not the only way to have a career in astronomy. Thousands of workers are involved in designing and running telescopes and observatories. These people are experts in mechanical engineering, computer engineering, and software design. To exclude these careers misleads students on the incredibly broad range of career possibilities in astronomy and space science. Even worse, focusing on astrophysics as the only path to a career in astronomy reinforces the universal myth that you have to be a mathematical genius to have a science career.

Students interested in astronomy careers should know that a variety of educational paths exist that can match their abilities and interests. Students also need to understand that while most scientists work hard to learn math and science concepts, most succeed in achieving their goals. — *Horton Newsom, Institute of Meteoritics and Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque*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NASA's Shuttle Radar Topography Mission (SRTM) used radar to produce images of about 80 percent of Earth's landmass, including some 3-D shots. This view shows Sierra Colorado, Argentina.

Astronomy graduates go on to a variety of careers. I studied astronomy at Glasgow University and gained an Honours Degree in 1981. I then joined the Royal Air Force as a fighter pilot and am now an airline captain. The view at 37,000 feet at night, even over a city, is incredible from the flight deck. Personally, I chose astronomy purely for interest's sake and enjoyed it immensely. I now consider myself an informed amateur.

So I guess my message is simple: Astronomy is a great subject and you don't need to be considering a professional career to study it. — *Graeme Smith, Ayrshire, England*

3-D Rinky Dink?

I love *Astronomy* and all its great photos. Surely we don't need the "rinky-dink" comic book nonsense that ruined the December 2000 issue. Instead, let's see those 28 photos "for real" in some future issue. — *Richard J. Swartwout, Penn Laird, Virginia*

I greeted the December 2000 issue with great excitement. Now you've gone and done it — you've spoiled me. I want all of your photos in 3-D! — *Jerry Leavins, Hitchcock, Texas*

Area Code Corrections

I enjoyed "Stars Shine Over Tinseltown" (December 2000). However, the article listed some incorrect area codes for phone numbers on page 80.

Use area code 323 for the various numbers listed for contacting the Griffith Observatory. Also, the correct phone number for the Los Angeles Astronomical Society (LAAS) is (213) 673-7355. — *Roger A. Keen, Griffith Observatory lecturer and past president of the Los Angeles Astronomical Society*

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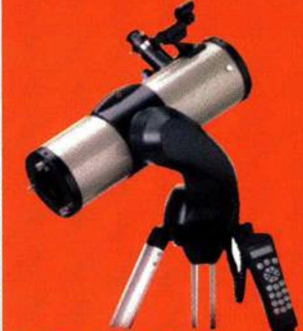

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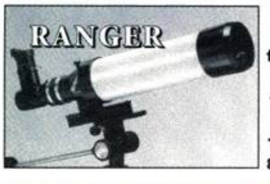

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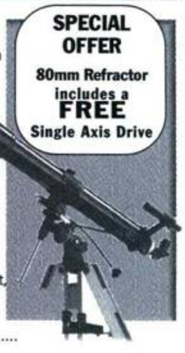

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EXTRASOLAR PLANETS

Lonely, Dim Objects Spark Big Debate

▶ A team of astronomers has discovered 18 free-floating, low-mass objects in the Sigma Orionis star cluster. These dim, relatively nearby objects, likely between 1 million and 5 million years old, are believed to have masses ranging from 5 to 15 times that of Jupiter.

Reporting in the October 6, 2000, issue of *Science*, Maria Rosa Zapatero Osorio of the Institute of Astrophysics of the Canaries in Tenerife, Spain, and her collaborators contend that these objects are a "new kind of isolated, giant planet" and that their results present a serious challenge to current planet-formation theories.

Some astronomers have reacted strongly to the team's use of the word planet. As Zapatero Osorio and her colleagues state, it's doubtful that these objects formed in the same way that planets like Earth and Jupiter presumably formed — over millions of years as gas and dust coalesce in a circumstellar disk. The team's analysis shows that the new bodies do not orbit stars. Rather, they appear to be interstellar vagabonds, wandering aimlessly through the cluster.

The apparent lack of orbital motion leads some researchers to assert that the objects shouldn't be classified as planets. Instead, they should be considered remnants of the process that formed the cluster. "This work is really about finding the low-mass cutoff for objects that form directly out of molecular cloud core collapse," warns Lynne Hillenbrand of Caltech. But because astronomers lack a rigorous definition for "planet," they are free to select the criteria — such as mass, method of formation, or the capacity to sustain nuclear fusion reactions — to distinguish between planets and substellar objects such as brown dwarfs.

Zapatero Osorio's team chose to define anything below 13 Jupiter masses — the minimum mass required to fuse deuterium — as a planet. Others disagree. "I don't think it makes good sense to call these objects planets simply based upon their apparent inability to burn deuterium, because they do seem to have formed in a different way [than the planets in our solar system]," cautions Alan Boss, a theorist at the Carnegie Institution of Washington. Boss would rather see astronomers call the new objects planetary-mass brown dwarfs.

Hillenbrand argues that astronomers need to reach a consensus regarding the classification of planets. "I think we need to have a debate over the question of whether we define a planet as something that coalesces out of dust and gas in a circumstellar disk or something that forms out of a direct collapse of the interstellar medium," she says. But Zapatero Osorio, now with the Division of Geological and Planetary Sciences at Caltech, sees the issue as a problem of semantics rather than a crisis of understanding. "If planets can only exist around a star, then our candidates are very low-mass brown dwarfs. But if planets are defined by their mass, then these are planets," she says.

Astronomers also caution that we should remain skeptical of the results. Joan

George Greaney

As many as 18 free-floating "planets" may wander the Sigma Orionis star cluster. (Sigma Ori is the bright star at lower right.)

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Najita of the National Optical Astronomy Observatories in Tucson, Arizona, warns that the objects may not even belong to the Sigma Ori cluster. "The region they studied covers a pretty large area," she says, "so the likelihood that they get foreground and background objects is fairly high." Zapatero Osorio's team concedes that as many as five of their candidates may be such spurious objects.

Though the results are still preliminary, the enthusiasm of the challenge they present runs high. "We've got strange new creatures to explain, so it is indeed an exciting time," says Boss.

— William Schomaker

EXTRASOLAR PLANETS

No Planets in Globular Cluster

▶ To hear many in the media, you'd think planets are popping up everywhere. Yet most searches for extrasolar planets have stuck close to home, scouring our local solar neighborhood while leaving huge tracts of the galaxy unexplored.

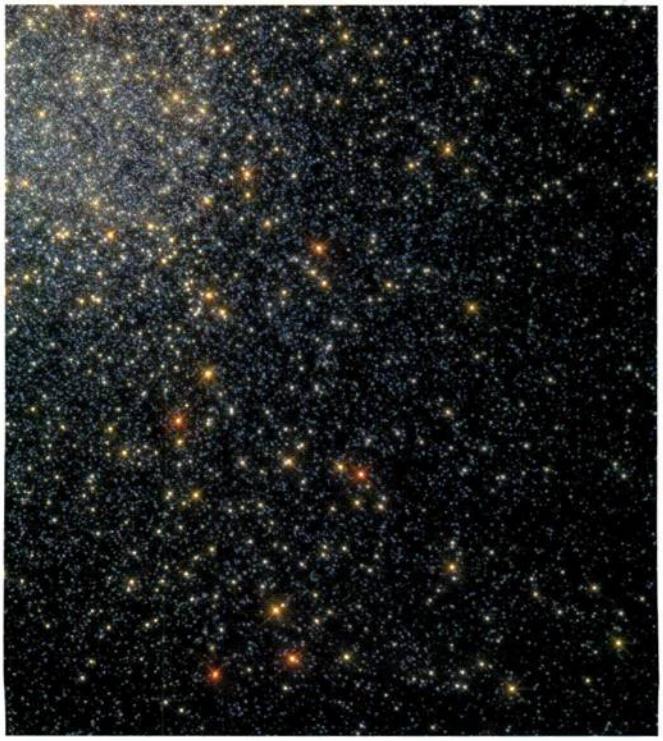
Now, in the first systematic search for planets beyond our neighborhood, astronomers have come up with a big fat zero. A team led by Ron Gilliland of the Space Telescope Science Institute (STScI) in Baltimore and Tim Brown of the National Center for Atmospheric Research in Boulder, Colorado, used the Hubble Space Telescope to scan the globular star cluster 47 Tucanae, located 15,000 light-years from Earth.

The researchers trained Hubble on part of the cluster for eight consecutive days, taking more than 1,300 images. They then examined 35,000 stars, looking for the telltale dip in brightness that would signal a planet passing in front of a star. Although the search turned up 100 variable stars, none of the variations had the signature of a transiting planet.

The team admits that the technique can detect only big planets in tight orbits — what astronomers call "hot Jupiters." The brightness dip from a smaller planet would be too subtle to see, and a planet in a large orbit would be unlikely to transit its parent star in eight days. Yet statistically about one percent of the stars near the sun have a hot Jupiter and 10 percent of these close planets should transit their star. The team expected to find 15 to 20 planets in 47 Tuc.

Possible explanations abound. Many astronomers think globulars are so old that they don't contain enough heavy elements to make planets. Also, the crowded environs in a globular could strip planets from stars or prevent a planet from migrating inward. Still, the result could prove profound. As STScI's Mario Livio says, "This could be the first tantalizing evidence that conditions for planet formation and evolution may be fundamentally different elsewhere in the galaxy." — Richard Talcott

Hubble images of globular cluster 47 Tucanae (below; a ground-based view appears at left) revealed no planets. Left: David Malin, © AAO; below: Ron Gilliland (STScI) and NASA



GALILEO MISSION

New Views of Volcanic Io

▶ A casual glance at a global image of Jupiter's moon Io reminds many first-time viewers of a bad experience in a pizza restaurant. Yet Io's pizzalike appearance belies the fierce gravitational tug-of-war going on between the moon and its parent planet, Jupiter.

During its five-year mission to study the jovian system, the Galileo spacecraft has rarely ventured near the constantly changing moon. However, in late 1999 and early 2000, Galileo successfully completed three close flybys, offering planetary scientists a unique chance to explore Io.

Data from the February 2000 flyby were released at the annual conference of the American Astronomical Society's Division for Planetary Sciences held last October in Pasadena, California. The data include the highest resolution images ever taken of the volcanically restless world.

High on the spacecraft's target list was the active volcano Prometheus, the "Old Faithful" of Io. Placing this volcano in context, Alfred McEwen of the Lunar and Planetary Laboratory in Flagstaff, Arizona, says, "It's the largest volcanic flow field anywhere in the solar system." The origin of its ever-present plume has been a long-standing mystery. The new images reveal bright streaks thought to be new small eruption vents, but the long-searched-for central vent seems nonexistent. Galileo scientists now

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conclude that a continuous stream of hot lava pushing into the yellowish sulfur dioxide-rich plains might account for the plume of Io's Old Faithful.

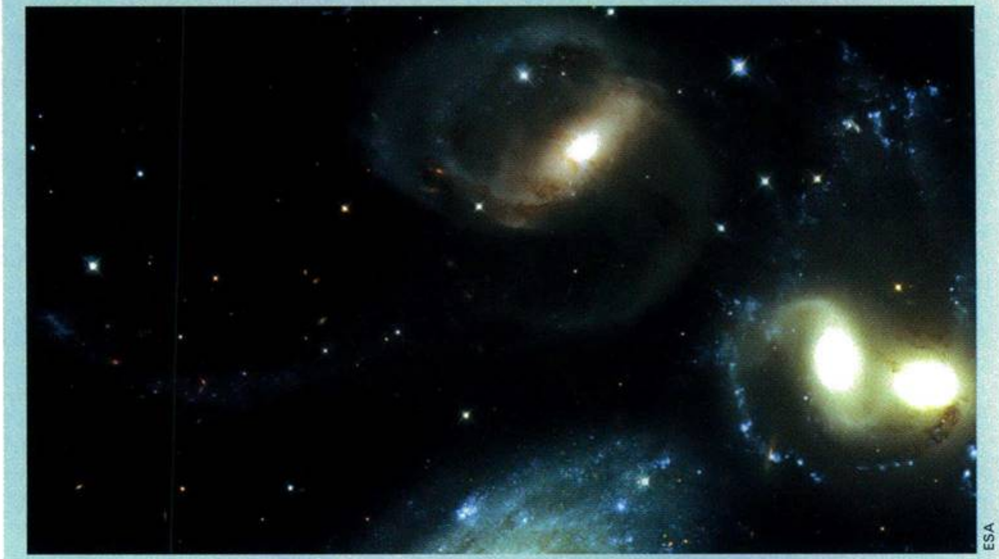
The highest resolution images of Io's bright plains, showing details as small as 40 feet across, reveal an undulating dunelike texture. "We are quite puzzled by the east-west trend of these ridges, though we're convinced it must be a volatile-rich material," says McEwen. The unusual textures of the surface features resemble melting snow, suggesting that Io's surface is covered with a sulfur dioxide-rich snow layer. Heat from lava flows and from the sun should concentrate this snow layer near the poles. Scientists still don't know why the snow appears all over Io.

One of the most prominent active volcanoes on Io is Pele. Seen by Voyager in 1979, Pele was placed under the temperature-sensitive eye of Galileo's Near Infrared Mapping Spectrometer (NIMS). The close flyby led to higher resolution data on the volcanic vents, providing more accurate temperatures.

NIMS showed temperatures in excess of 2700° Fahrenheit (1500° C). "The high temperatures indicate that the lava must be rich in magnesium and iron," says Rosaly Lopez-Gautier, the NIMS science coordinator for Io at the Jet Propulsion Laboratory in Pasadena, California. The composition of Io's lava "is thought to be similar to the deep mantle of Io," Lopez-Gautier adds. These temperatures are similar to those of the basaltic lavas that erupted on Earth billions of years ago, but earthly lavas today don't get anywhere near this hot. Scorching temperatures have been found in other ionian volcanoes, supporting the idea that hot lavas are widespread on Io.

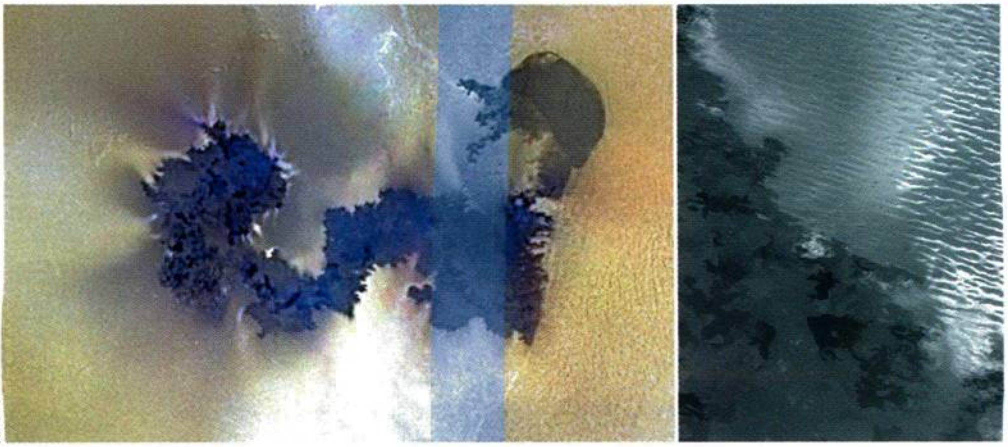
Although the new data prove illuminating, astronomers remain humble. The full puzzle of Io's origin and evolution remains to be solved. — MARTIN RATCLIFFE

HUBBLE SPACE TELESCOPE


ESA

AN INTRICATE COSMIC DANCE plays out in Pegasus, where galaxies collide and tidal interactions mold them into distorted shapes. Hubble captured the fireworks in this compact group of galaxies known as Stephan's Quintet. Historically, the group played a key role in the debate over whether a galaxy's redshift indicates distance. NGC 7320 (bottom) has a smaller redshift than the other galaxies, implying it lies closer. Astronomers now know that it *is* a foreground galaxy, some 35 million light-years away compared with 270 million light-years for the others. Hubble confirms this, resolving individual stars in that galaxy alone. Other observations show that NGC 7320C (off the left edge) passed through the group a few hundred million years ago, ripping out stars and gas to form a long tidal tail. And NGC 7318B (far right) is currently colliding with the group, triggering a massive burst of star formation (bright blue areas).

Io's Prometheus volcano (left) has no apparent central vent, but plumes may erupt where lava meets the cold plains. Erosion or surface folding may have formed mysterious ridges (right).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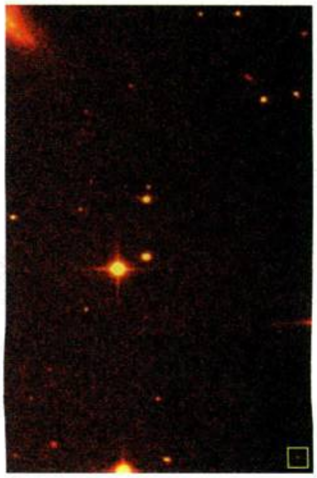
PLANETARY SCIENCE

Six More Moons for Saturn

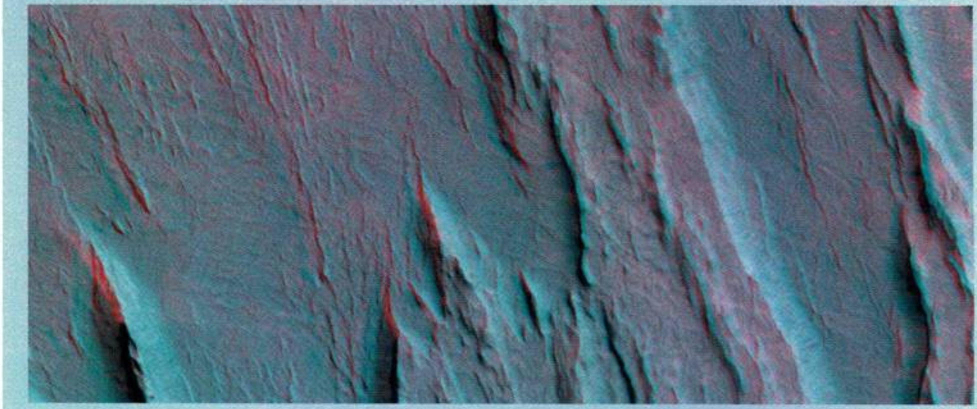
▶ Apparently, Saturn was just being neighborly to Uranus by loaning its crown as King of the Moons. But in late 2000, Saturn reclaimed the title when astronomers discovered six new moons orbiting the planet, bringing its total to 24 and leaving Uranus with its 21 in the dust.

Brett Gladman of the National Center of Scientific Research in Nice, France, and seven collaborators found the moons using a technique devised by Gladman. Once every hour, the researchers imaged a region of sky close to Saturn. Computer software then compared the images, looking for any object that moved relative to the fixed background stars. It's the same technique the team used between 1997 and 1999 to discover five new moons around Uranus.

One of six new moons around Saturn, S/2000 S 1 (square) glows dimly in this discovery image. (That's a spiral galaxy in the top left corner.) ESO



MARS GLOBAL SURVEYOR



NASA/JPL/MSSS

SHARP, ELONGATED RIDGES sculpted by fierce martian winds dominate this three-dimensional view of southern Elysium Planitia, a large plain located near the Red Planet's equator. (To see this Mars Global Surveyor image in stereo, use the red-blue 3-D glasses included with the December issue.) For wind to erode bedrock into patterns like these, the rock must consist of fine-grained material whose grains have nearly the same size. On Mars, that likely means volcanic ash. A thin layer of dust covers the entire region, and small landslides in this layer form the dark streaks seen on some of the steeper slopes. The stereo image combines an oblique view taken in January 1998 with a straight-down view from October 2000. The area extends 4.2 miles (6.7 kilometers) across and 1.5 miles (2.5 km) top to bottom. The vertical relief has been exaggerated to show detail — the ridges actually rise between 165 and 330 feet (50 and 100 meters) above the rest of the surface.

The moons — preliminarily designated S/2000 S 1 through S/2000 S 6 — were first spotted with either the European Southern Observatory's 2.2-meter telescope at La Silla, Chile, or the 3.6-meter Canada-France-Hawaii Telescope on Mauna Kea in Hawaii. Glowing dimly between magnitudes 20 and 26, the objects must be small. The team estimates their diameters at somewhere between 6 and 30 miles (10 and 50 kilometers), depending on what fraction of the incoming sunlight their surfaces reflect.

All appear to be irregular satellites, having elongated orbits that stretch several million miles from Saturn and lie well out of the plane of the planet's equator. Before these discoveries, astronomers knew of only one irregular satellite around Saturn, Phoebe, which was discovered in 1898 by William Pickering. Phoebe and S/2000 S 1 are the only two that orbit Saturn in a retrograde manner, opposite the direction of the planet's spin.

All of Saturn's bigger moons lie closer to the planet and travel in nearly circular orbits in the planet's equatorial plane. Astronomers suspect these coalesced from a disk of gas and dust that surrounded Saturn as it was forming. The new outer moons apparently were captured into their current orbits long after the planet formed. — R. T.

NEW TELESCOPES

Gemini Reveals Galaxy's Center

▶ The latest weapon in an expanding arsenal designed to probe the mysteries of the universe has fired its initial salvo. The 8-meter Gemini Telescope, located on Mauna Kea in Hawaii, made its first scientific observations in July and August 2000.

The dramatic glimpse into the core of the Milky Way Galaxy gives a snapshot of the chaotic activity that reigns within a few light-years of the center. "Never before have we seen such a large area of the galactic center this clearly," says project leader François

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Rigaut of the Gemini Observatory.

A supermassive black hole with a few million times the mass of the sun lurks at the center, wreaking havoc on its surroundings. One intriguing result appears just 3 light-years from the galaxy's center, where a wayward star plows into a cloud of gas and dust.

The collision creates an obvious bowshock, similar to the wave that forms in front of a boat as it speeds through water. The object, cataloged as IRS8, appeared only as an ill-defined smudge until Gemini came along. By studying how the star interacts with the cloud, astronomers hope to better understand the physical conditions at the galactic center.

The color image does not reflect what the human eye would see. Observations were made at several infrared wavelengths and then combined to create the false-color image. Thousands of light-years of gas and dust lie between Earth and the center, and precious little of the light emitted in the interior makes it out to the galactic suburbs. Most of the surviving radiation lies in the infrared part of the spectrum.

The Gemini Observatory was designed to make the most of this infrared trickle. Optimized for infrared observations and located at one of the premier sites for infrared astronomy, Gemini also uses adaptive optics to correct for the distortions in starlight caused by turbulence in Earth's atmosphere.

These science observations took place during the preliminary science testing period. Gemini North should begin full scientific operations in early 2001 while Gemini South — a near twin located on Cerro Pachon in Chile — will follow about six months later. — R. T.

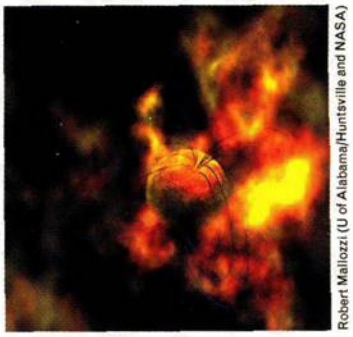
An intriguing bowshock (at upper right) near the Milky Way's center highlights the first science image from the 8-meter Gemini North Telescope. Gemini Observatory

Life Could Have Arrived from Mars

While humans have yet to make the trip, meteorites have certainly traveled between Mars and Earth. Some scientists even believe that microbial life could have started on Mars and hitched a ride to Earth. But could a meteorite get blasted off Mars without frying such life? In the October 27, 2000, *Science*, Caltech graduate student Benjamin Weiss and his colleagues report that tests of the celebrated martian meteorite ALH84001 show it never got hotter than 105° Fahrenheit (40° C) at any time from when it left Mars until it landed in Antarctica. "What's exciting," says Weiss, "is that it shows the martian meteorite made it from the surface of Mars to the surface of Earth without ever getting hot enough to destroy bacteria, or even plant seeds or fungi."

Nuclear Explosion Wracks Neutron Star

Imagine a three-hour burst that produces 20 times more energy than the sun does in a year. That's just what astronomer Tod Strohmayer of NASA's Goddard Space Flight Center saw with the Rossi X-ray Timing Explorer. The culprit: a neutron star 20,000 light-years away in the binary system 4U 1820–30. The neutron star lies in a tight orbit — its 11-minute period is the shortest known — with a helium-rich companion. Its intense gravity pulls gas from the companion and, once enough collects on the surface, ignites a modest nuclear explosion. (Astronomers often see neutron star bursts that last for about 10 seconds and generate less than one percent the energy of the megaburst.) Strohmayer thinks the big burst came when the carbon ash generated in the helium explosions accumulated to a Pluto's worth of material and it, too, detonated.



Robert Mallozzi (U of Alabama/Huntsville and NASA)

An artist envisions what a neutron star would look like up close.

Another NASA Mission Bites the Dust

Planetary scientists, still reeling from the cancellation of the Pluto Kuiper Express mission, were dealt another blow in early November when NASA halted development of a miniature rover. The rover would have been part of the U. S. contribution to the Japanese MUSES-C mission, the first asteroid sample-return mission that's scheduled for launch in late 2002. Originally priced at $21 million, the development cost had ballooned to $60 million and was rising. "The decision to cancel the MUSES-C nanorover was difficult and distasteful," says Jay Bergstralh, NASA's Acting Director of Solar System Exploration, "however, there was no viable alternative."

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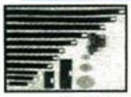

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E mail: pwo@PoconoScopes.com

Mention Ad A-7

Anyone can sell you a telescope.

Authorized Meade Dealer

Meade ETX-90EC
$595
Meade ETX-125EC
$895
#497 Autostar
$149

Hardly a day goes by that we don't get a note or E-mail message like the one reprinted on the next page, or a call that goes something like this: "Your ads are right. Dealer so and so advertises low prices – but they don't have what I want in stock, they couldn't answer *any* of my questions, and they wanted my credit card number before they'd even *talk* to me. They said if I wanted to ask questions, I should call the manufacturer . . . and then they hung up on me!"

If you want the right telescope, you need more than a camera store clerk armed with only a price list and not a clue in the world about astronomy.

What you *really* need are people who will take the time to listen to what *you* need, people who can can answer your questions, people with years of experience using and selling telescopes who can help you get the most telescope for your dollar. That's exactly the kind of people you'll find at ***astronomics***.

Unlike camera stores and shopping mall gift shops, telescopes are our specialty at ***astronomics***, not just a sideline. We're a family-owned full-line telescope dealer – not just a few toy telescopes stuck off in the corner of some no-help department store, toy store, or gift shop as an afterthought. And, unlike department store clerks, we don't work on commission, so we won't try to sell you more than you need just to pad our paychecks.

We've been helping people choose the right telescope since 1979. We have the experience to help *you* pick the scope that fits your needs . . . *and your budget* . . . from the many Meade, Celestron, TeleVue, Takahashi, and Questar telescopes we stock at discount prices from $99 to $27,995.

And we can usually ship your right telescope right away. We had *1124 scopes in stock* as we wrote this on 11/5, and an additional 1000+ on order!

astronomics. No hard sell. No guesswork. Just honest advice, the *right* scope, and a good price. Call us at (405) 364-0858 and find out for yourself.

The new 8" Meade LX90 is in stock!

Meade
8" LX90
$1695

You can live the good life of big-aperture fully computerized go-to astronomy for less money than ever before with the new 8" **Meade LX90**.

The 8" LX90 SCT is only $1695, including a tripod and a go-to Autostar computer with 30,223 stars and objects in its data base.

We've already shipped almost 100 LX90 telescopes to people on our waiting list, and more scopes are arriving weekly, so the chances are good you can get an LX90 with little or no delay. While backorders *are* possible on this new scope, if Meade is shipping the LX90 for a dealer to keep in stock, chances are good we *have* it in stock.

Meade prices are about the same anywhere you call. So why order a Meade scope or accessory from a dealer who charges your credit card, then makes you wait and wait until he finally gets around to ordering what you want? Not when you can usually get the Meade you want . . . right now . . . at the right price . . . right here at ***astronomics.***

We buy telescopes by the ton . . . literally!

The day before this copy was written, we received 305 cartons from Meade – *3¼ tons* of scopes and accessories in one shipment. Earlier in the same week, we received 9791 pounds of Celestron scopes and accessories in a single shipment – 21 pallets, a full trailer load. We don't know of many dealers – if any – who stock Celestron and Meade products in those quantities . . . *no matter what they claim.* But we do. Telescopes, eyepieces, filters, CCD cameras and autoguiders, dew caps, Barlows, off-axis guiders, illuminated reticle eyepieces, electric focusers, T-adapters, tele-extenders, counterweights – we keep them all in stock.

Super starter scopes.

Left, Meade ETX-60AT, **$299**; *above,* Meade ETX-70AT, **$349**

The new 60mm **Meade ETX-60AT** and 70mm **ETX-70AT** refractors hit a new low in pricing for fully computerized scopes . . . and a new high in value! For less than the cost of many single eyepieces alone, you can have a complete scope – with dual axis motor drives, two eyepieces, built-in go-to computer with 1471 stars and objects in its memory for pushbutton astronomy, and more!

They're ideal as starter scopes, as second scopes for casual astronomy, as vacation scopes, as scopes for the kids. Any way you look at them, these new Meade scopes are winners!

We stock Pentax XL eyepieces.

PENTAX

From 5.2mm to 40mm, we stock all the Pentax wide field (55° to 65°) XL eyepieces. Each has a rotate-to-adjust-eye-relief eyecup, ED glass, and a long 20mm eye relief that's perfect for those who wear eyeglasses. Premium eyepieces . . . sensible prices.

7mm (1.25" 65° field) .... **$\$279^{00}$**
10.5, 14, 21 (1.25" 65° field)
or **28mm** (1.25" 55° field) .... **265^{00}**
5.2mm (1.25" 65° field)
or **40mm** (2" 65° field) .... **289^{00}**

We also stock the new Pentax XL 8 to 24mm 1.25" ED glass zoom eyepiece (38° to 60° field). Like the other Pentax eyepieces above, it has a rotate-to-adjust-eye-relief eyecup and long eye relief at all magnifications for unvignetted use with eyeglasses. ..... **$\$439^{00}$**

We have the Meade ETX-125EC in stock!

Meade 5"
ETX-125EC
$895

We have over 100 **ETX-125EC** 5" Maksutov-Cassegrains in stock, with more scheduled to arrive in the near future. You don't have to wait to get an ETX-125EC from ***astronomics.***

We've sold over 500 of these 5" computerized Meades during the past year, and 250 of its smaller brother, the 3.5" ETX-90EC. Add in the new 60mm and 70mm ETX refractors, and the Meade ETX scopes make up the most popular family of go-to scopes we carry.

And we don't just have ETX scopes in stock. We have Autostar computers, cases, tripods, eyepieces, electric focusers, filters, camera adapters, and more. If it's any of the Meade ETX scopes, or an accessory for a Meade ETX – *or any Meade telescope* – chances are good that we have it in stock.

Over 1,000,000 people a year visit our redesigned and expanded website, now with secure on-line shopping.

www.astronomics.com

3-day air shipping for the cost of shipping by ground!

We ship by UPS three-day air from our centrally-located warehouse to our East and West Coast customers for the same price as regular ground shipping (except for a few big scopes, scope cases, Dobsonians, dewshields, and a few other bulky items). No matter where you live in the 48 continental United States, your order should arrive by the third business day after we ship. UPS can't guarantee 3-day delivery in case of bad weather or during peak seasons, so UPS service guarantees do not apply to this limited time free upgrade if shipments are delayed.

Our free catalog helps you pick the right Meade, Celestron, Questar, Takahashi, or TeleVue scope.

For detailed information on individual products, visit our Web site. Or call us at (405) 364-0858, or e-mail us, for your *free* copy of our catalog AST. It covers all the scopes and accessories we stock – from Apogee, Bushnell, Canon, Celestron, JMI, Lumicon, Meade, Pentax, Questar, Rigel Systems, SBIG, Software Bisque, Takahashi, TeleVue, and more. We'll include our 8-page guide on how to pick the right scope and your discount prices on the 1000+ products we carry. (Sorry, U. S. sales only.) The catalog is yours for only the cost of a one minute phone call. The information we send will make it the most useful minute you'll ever invest in astronomy.

astronomics

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Toll-Free Order Line: **(800) 422-7876** Catalogs/Questions/Advice: **(405) 364-0858**

We'll sell you the *right* telescope.

TMB triplet apos!

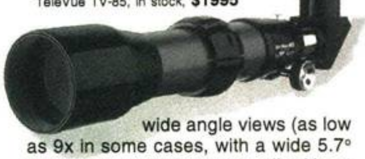
TMB 100

The first TMB refractors are in the hands of some very delighted customers of ours. Visit our website to see the scopes that are the talk of experienced astronomers everywhere.

TMB 80/6	80mm (3.1") f/6 triplet apo	**$1390^00**
TMB 80/7	80mm (3.1") f/7 triplet apo	**1390^00**
TMB 100	100mm (4") f/8 triplet apo	**3290^00**
TMB 105	105mm (4.1") f/6.2 triplet apo	**3290^00**
TMB 130	130mm (5") f/6 triplet apo	**4990^00**
TMB 152	152mm (6") f/7.9 triplet apo	**6990^00**
TMB 175	175mm (7") f/8 triplet apo	**11,990^00**
TMB 203	203mm (8") f/9 triplet apo	**19,990^00**
TMB 254	254mm (10") f/9 triplet apo	**39,995^00**

TeleVue? We keep it in stock.

TeleVue TV-85, in stock, **$1995**



Hardly a week goes by that TeleVue doesn't send us copies of warranty cards filled with the glowing comments written by our our customers about the TeleVue scopes they bought from us. But we don't need to be reassured about TeleVue quality. We expect nothing but praise for TeleVue, which is why we stock them in depth. As this was written (11/5), we had dozens of TeleVue scopes in stock, including the TV-101, TV-102, TV-85, Renaissance, Prontos and Rangers galore, and two score more on order.

Pronto, **Ranger**, **TV-85**, **TV-101**, the **TV-102** optical tube, the **Renaissance** – all are built to uncompromisingly high optical and mechanical standards. Their short focal lengths give you an observing flexibility many other scopes lack. Each has the ability to go from very low power wide angle views (as low as 9x in some cases, with a wide 5.7° field) to very high power, all without losing optical quality (one test report said they used an amazing 89x per inch of aperture on TeleVue's least expensive model, the Ranger).

In addition to telescopes, we stock TeleVue eyepieces; Barlows; camera adapters; Gibraltar, TelePod and Panoramic mounts; Sky Tour computer systems, Air Chairs; Starbeam and Qwik-Point finders, and all other accessories in depth. If it's from TeleVue, chances are good we have it in stock for immediate shipment.

TeleVue eyepieces, all models in stock

Fuji astro binoculars!

You may have read that comet Hyakutake, among others, was discovered with big 25 x 150mm and 40 x 150mm Fujinon binoculars. There's no guarantee that you'll discover a new comet with a Fujinon 10 x 70mm or 16 x 70mm FMT-SX binocular, but we can guarantee that the 70mm Fujinons are built to the same optical quality standards as the big Fujis. For pricing and full details, see our newly redesigned and expanded website at **www.astronomics.com**.

I just wanted to let you know that a whole lot of people involved in amateur astronomy have repeatedly directed me to you and your company as not only being reputable but down right pleasurable to deal with.

After speaking with you earlier today I see what they were talking about.

As an attorney, I usually deal all day, every day, with individuals whom polite society would refer to as "doody-heads". I have found the same to unfortunately apply, all too often, to astronomical businesses and have been badly burned - more than once (although never twice by the same person or business).

I was pleasantly surprised to the point of shock at how friendly and informative you were - it truly made my week. You can be assured that there will be more business to follow - it's my pleasure.

Customer Quote of the Month #107

CCD? We carry Apogee LISÄÄ, Meade, and SBIG.

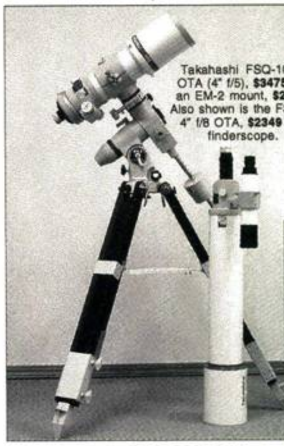
We stock almost all available models of the Apogee LISÄÄ, Meade, and SBIG CCD cameras and auto-guiders (like the new **Apogee LISÄÄ** 659 x 494 pixel guider or imager to the left and the *self-guiding* 1534 x 1020 pixel **SBIG ST-8E** enhanced blue sensitivity imager shown to the right). Our large inventory means the chances are good you won't have to wait to get the camera of your choice. Here are the cameras and guiders we normally keep in stock and their prices.

Apogee LISÄÄ	autoguider or camera	**$1495^00**
Apogee LISÄÄ	camera	**1395^00**
Apogee LISÄÄ	color camera	**$1395^00**
Apogee LISÄÄ	megapixel camera	**2595^00**
Apogee LISÄÄ	megapixel color	**2595^00**
Apogee LISÄÄ	guider + color	**2690^00**
Apogee LISÄÄ	guider + megapixel	**3890^00**
Meade 201XT	autoguider	**395^00**
Meade 208XT	autoguider or camera	**495^00**
Meade 216XT	16-bit camera	**695^00**
Meade 416XTE	camera/guider pack	**1995^00**
Meade 1616XTE	camera/guider pack	**6495^00**
SBIG ST-4	autoguider or cameraa	**890^00**
SBIG ST-5C	track/accumulate camera	**895^00**
SBIG ST-237	track/accumulate camera	**1195^00**
SBIG ST-6B	track/accumulate camera	**3025^00**
SBIG ST-7E	self-guiding camera	**2950^00**
SBIG ST-8E	self-guiding camera	**7350^00**
SBIG ST-9E	track/accumulate camera	**3950^00**
SBIG STV	digital video camera/guider	**1595^00**
SBIG STVD	digital video w/LCD screen	**1995^00**

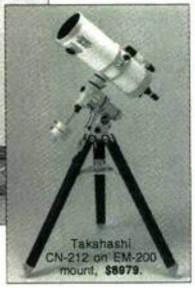
Our Takahashi sales are now up 263% this year.

Why are more and more people buying more and more Takahashi from us? Is it because we stock more Takahashi than just about anyone else?

While many people swear *at* the long delivery times quoted by some premium refractor manufacturers, most knowledgeable astronomers swear *by* the unsurpassed optical quality and fast delivery of the Takahashi apochromatic refractors we keep in stock.



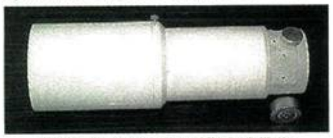
Takahashi FSQ-106N OTA (4" f/5), **$3475**, on an EM-2 mount, **$2229**. Also shown is the FS-102 4" f/8 OTA, **$2349** w/o finderscope.



Takahashi CN-212 on EM-200 mount, **$8979.**

From the 2.4" **FS-60C** OTA at $829 to the 6" **FS-152** OTA at $8999, we stock Takahashi fluorite apochromatic doublet refractors, mounts, and accessories – so we can deliver scopes *fast*. We can also special order larger scopes with 1-3 month delivery times. Why wait for 1-3 *years* to get your apo refractor or mount from another manufacturer? You can be usually be viewing through a truly superb Takahashi apo only a few short days after you order from us.

We stock complete Takahashi scopes on USD mounts with 50x sidereal dual-axis slewing, as well as apochromatic optical tubes for use on your own mount.



Takahashi FCL-90 ***Sky 90*** OTA (3.5" f/5.6), shown with dew shield retracted, **$2279**

Arriving this fall is Takahashi's unique **FCL-90 *Sky 90*** 90mm f/5.6 refractor. With its self-storing dew shield retracted, as shown above, this remarkable scope is less than 14" long! Combined with a compact P2Z mount, it makes a great traveller you can stow away anywhere.

We also stock the 22" long Takahashi **FSQ-106N** 4" 4-element f/5 dual fluorite apo refractor OTA, with retractable lens shade, shown to the far left at $3475. It's also a great travelling scope. We had 5 in stock as we wrote this on 8/5.

In stock is the unique Takahashi **CN-212** reflector, shown left on a mid-size EM-200 mount ($6999 on a compact EM-10 mount). It's both a fast 8.3" f/3.9 Newtonian for 35mm and CCD astrophotography *and* an f/12.4 classical Cassegrain reflector for high contrast visual observing.

If you want a great scope, and you want it *now*, your first choice should be a Takahashi from ***astronomics***.

Go-to computerized scopes you assemble in minutes!

CELESTRON

~~$858 list~~

$499 114GT

~~$658 list~~

$399

80GT

You won't spend hours assembling these **Celestron NexStar** go-to scopes. They're preassembled, so all you do is slip the scope base into the tripod, hand tighten one large knob, and you're ready to observe . . . with no tools needed! You get two eyepieces, a Star Pointer finder, dual motor drives, an adjustable height tripod with accessory tray, and a 4000+ object go-to computer. The **Celestron NexStar 114GT** to the left is a 4.5" aperture 1000mm focal length f/9 reflector. The **Celestron NexStar 80GT** to the right is a 3.1" aperture 400mm focal length f/5 refractor. Both are so sensationally easy to assemble and use that you'll be observing a mere 10 minutes after you get one.

One small step for man. One quantum leap for binocular observing!

$1499

Canon

"Truly a quantum leap in binocular observing," is what *Sky & Telescope* said about the Canon image-stabilized binoculars. They also said "astounding . . . supercrisp . . . particularly impressive was how well these binoculars compared to much larger apertures . . ." There's no shake, no blur, no jittery images during hand-held, rock-solid, astronomical observing. The newest image-stabilized Canon binoculars are the 15 x 50mm, shown to the right, and a higher power 18 x 50mm. A useful option with both binoculars is a pair of specially coated fog-proof eyepieces that help keep the images sharp and moisture-free all night long.

24-Hour FAX line: (405) 447-3337   Our e-mail address: questions@astronomics.com

Our multiple award-winning Internet address: www.astronomics.com

Our phone lines are open 10 to 7 CST, Monday thru Friday, and most Saturdays from 12 to 5.

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No credit card surcharge. $6.95 minimum freight. All returns less freight. Restocking fees apply to returns for credit and to merchandise returned used or damaged.

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NexStar 8
CELESTRON

Two BIG items from the NexStar Family

First: The price of the NexStar 8 has DROPPED to $1,699. Second: Celestron has added 3 new beginner sized telescopes to the NexStar family

NexStar 60 GT
60mm f/12 refractor w Go-To Mount $299
NexStar 80 GT
80mm f/5 refractor w Go-To Mount $399
NexStar 114 GT
114mm f/9 Newtonian w Go-To Mount $499

Other Celestron Telescopes at Lumicon

NexStar 5	$1199
Ultima 2000	$2699
Celestar Deluxe	$1699
Celestar	$1099
CM 1100– 11" SCT	$3199
Starhopper 8" Dob	$429
Starhopper 6" Dob	$339
C102-HD 4" Refractor	$549
FirstScope 114	$299
CR150 6" f/8 Refractor (REDUCED!)	$799

At Last!! Advanced Santa Barbara Instruments CCDs available thru Lumicon . . . the experts in astrophotography!

SBIG
ASTRONOMICAL INSTRUMENTS

Lumicon is proud to announce that we are now an authorized dealer for quality Santa Barbara Instruments CCD cameras and accessories. Here is just a sample of what is available.

ST-4, Auto Guider 192x 164 pixels	$890
ST-237, Imager 640 x 480pixels	$1195
ST-5C, Imager 320 x 240 pixels	$895
ST-7E, Imager 765 x 510 pixels	$2950
STV Video Camera Deluxe	$1995

And much, much more!!! Call Lumicon, the experts in astrophotography, for all of your CCD needs.

LUMICON FILTERS - BEST IN THE WORLD BUT WHICH FILTER TO BUY?

LUMICON H-BETA
LUMICON OIII
OIII
LUMICON UHC
LUMICON DEEP-SKY

Lumicon Deep Sky Filters follow the classic broad band curve but offer the highest transmission of nebula lines of any such filter available. Lumicon Deep Sky filters block mercury and sodium vapor lamp emissions while letting thru all other parts of the spectrum. Deep Sky Filters are most useful for astrophotography (color & b&w) and CCD work. Deep Sky Filters are also useful visually, nebula offering the best contrast gain but galaxies, star clusters and dusty comets are also slightly enhanced.

1.25" Deep Sky Filter (fits most 1.25" eyepieces)	$99.50
48mm Deep Sky Filter (fits 2" eyepieces and Lumicon accessories)	$199.50
Visual Back Deep Sky Filter (fits in series on back threads of SCT'S)	$199.50
2" Deep Sky Filter (fits 2" eyepieces and T-threaded accessories)	$199.50
72mm Deep Sky Filter (for the front of large telephoto lenses*)	$399.50

*step rings for other sizes available.

Lumicon Ultra High Contrast Filters have a narrow band pass that lets thru the two oxygen III and the hydrogen beta lines while blocking the remaining visual spectrum. The resulting filter yields high contrast views of all types of nebula. It is best used visually with any telescope of f/6 or longer focal ratio. The Ultra High Contrast Filter is not for photography.

1.25" Ultra High Contrast Filter (fits most 1.25" eyepieces)	$99.50
48mm Ultra High Contrast Filter (fits 2" eyepieces and Lumicon accessories)	$199.50
Visual Back Ultra High Contrast Filter (fits in series on back threads of SCT'S)	$199.50

Lumicon Oxygen III filters isolate just the two oxygen III lines of the spectrum and block the remaining visual spectrum. The Oxygen III filter yields the maximum contrast gain possible on planetary nebula and most emission nebula. Views of the Veil Nebula and others with this filter are beyond words. The Lumicon Oxygen III Filter is for visual use only and is best suited for 6" and larger aperture telescopes with focal ratio of f/10 or faster.

1.25" Oxygen III Filter (fits most 1.25" eyepieces)	$99.50
48mm Oxygen III Filter (fits 2" eyepieces and Lumicon accessories)	$199.50
Visual Back Oxygen III Filter (fits in series on back threads of SCT'S)	$199.50

Lumicon Hydrogen Beta Filters isolate just the hydrogen beta line of the spectrum and block the remaining visual spectrum. The Hydrogen Beta filter was created with a select number of low energy nebula in mind such as the Horsehead, Cocoon & the California nebula. In many instances the Hydrogen Beta filter is the **ONLY** way to see these nebula. The Hydrogen Beta Filter is a visual filter only, best suited to 8" or larger aperture telescopes with focal ratios of f/5 or faster.

1.25" Hydrogen Beta Filter (fits most 1.25" eyepieces)	$99.50
48mm Hydrogen Beta Filter (fits 2" eyepieces and Lumicon accessories)	$199.50
Visual Back Hydrogen Beta Filter (fits in series on back threads of SCT'S)	$199.50

Special Pricing – Buy two or more Lumicon filters and get a DISCOUNT.

Filters normally priced at $99.50	pay only $92.50
Filters normally priced at $199.50	pay only $185.00

SKY VECTOR™ $349!!!

Includes Computer, Encoders, Hardware

LUMICON Sky Vector Features:

- "GUIDE" mode leads you to object
- Digital right ascension readout to 1 min.
- Digital declination reading to 10 arc/min.
- 4000 pulse (0.09 accuracy) encoders
- Polar Alignment NOT REQUIRED!
- Motor drive NOT REQUIRED!
- Just two stars to align
- Works Equally well for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080.
- No need to enter latitude, longitude etc.

SKY VECTOR I™ **$349.00**
NEW! With over 220 object memory including the 110 Messier and 58 best NGC objects.

NGC-SKY VECTOR™ **$489.00**
12,000 objects! PC serial port NGC Sky Vector with IDENTIFY (Sky Tour) mode; 12,000 object memory including the corrected RNGC catalogue, IC catalogue, P&K planetary catalogue and much more.

NGC-Sky Vector
MODE
ENTER
UP
DOWN
LUMICON

Specify Telescope Type: Meade 4",8", 10",12" SCT, C-8, C-11, Odyssey 8", 10", 12", 17$^{1/2}$" alt-azimuth; Meade 6"-16" Dobsonian. Ultima 8", 9 $^{1/4}$", 11" add $25. C-14 add $75.

TELE VUE PRODUCTS

4X Powermate for 2" eyepieces	$265
5X Powermate boosts magnification 5x	$168
Ranger 70mm f6.8 apchromat w/1$^{1/4}$" diag.	$695
Pronto 70mm f6.8 w/1$^{1/4}$" diagonal.	$945
Tele Vue 85, 85mm f/7 APO telescope	$1995
Bino Vue binocular w/2x correc.	$1030
Gibraltar mount with ash wood tripod	$530
8,11,15mm Plossl . $82 — **20,25mm**	$95
32mm Plossl, widest true field in 1$^{1/4}$"	$110
55mm Plossl, widest possible field	$230
2.0x or 3.0x Tele Vue Barlow Lens	$105
2" Giant Barlow – 2x	$168
4.8mm Nagler 82° field, 1 1/4 " eyepiece	$175
7mm Nagler, 1$^{1/4}$ " eyepiece, 82° field	$220
9mm Nagler, 82° field 1$^{1/4}$ " or 2"	$240
12mm Nagler Type 4, 82° 1 1/4 "or 2"	$340
16mm Nagler Type II, 82° 1 1/4 "or 2"	$310
17mm Nagler Type 4, 82° 2" only	$370
22mm Nagler Type 4, 82° 2" only	$445
31mm Nagler Type 5, 82° 2" only	$595
2" Paracorr tunable coma corrector	$280
3,4,6,8,10,14mm Radian, 60° field	$228
18mm Radian, 60° field	$228.
15mm Panoptic 1$^{1/4}$", 68° field	$210
19mm Panoptic 1$^{1/4}$", 68° field	$240
22mm Panoptic 1$^{1/4}$"/2", 68° field	$280
27mm Panoptic 2", 68° field	$330
35mm Panoptic 2", 68° field	$365

Note: Tele Vue warranty may not be valid outside USA

Tele Vue's Newest!

Lumicon, always in the forefront bringing you the latest scopes and specials, brings you the newest scope from Tele Vue. The Tele Vue 102 (shown with optional Gibralter Mount) brings you the best of apochromatic optics in a longer 880mm f/8.6 length making it and even better choice for planetary viewing than previous releases.

Tele Vue 102 tube assembly only	$2050
Tele Vue tube holder for 102	$120
Tele Vue Ash Gibralter Mount	$530
Lumicon 2" Enhanced Aluminum Star Diagonal	$189.50
Lumicon 2"/1.25" Reducer	$25

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FAX 1-925-447-9589 ▪ Prices subject to change without notice
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Sat. 10AM/3PM pst 1-925-447-9570

Telescopes and Accessories

ORDER TOLL FREE
1-800-767-9576

Lumicon H-Alpha Pass Filter

The Lumicon H-Alpha Pass Filter is a powerful light pollution filter for astrophotography near city lights. The light curve of the H-Alpha Pass Filter is ideal for use with Hypered Tech Pan film or with CCD Cameras for the highest contrast and sharpest detail. (NOT for Solar viewing!) Comes in three sizes with step rings to most other sizes available.

48mm H-Alpha Pass Filter	$59
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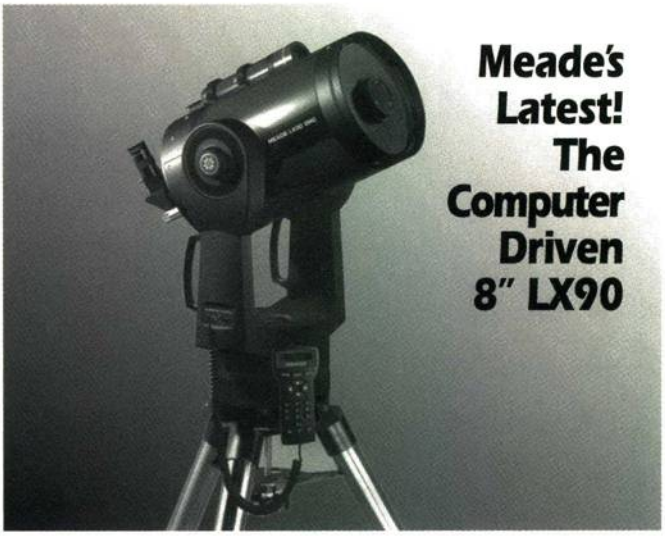

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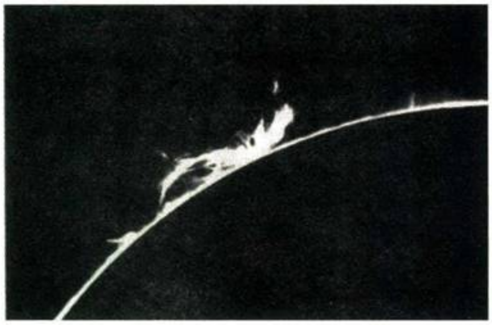

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Here, There, and

The latest Hubble observations are presenting a cosmological challenge as astronomers uncover supermassive black holes at the heart of every galaxy they examine.

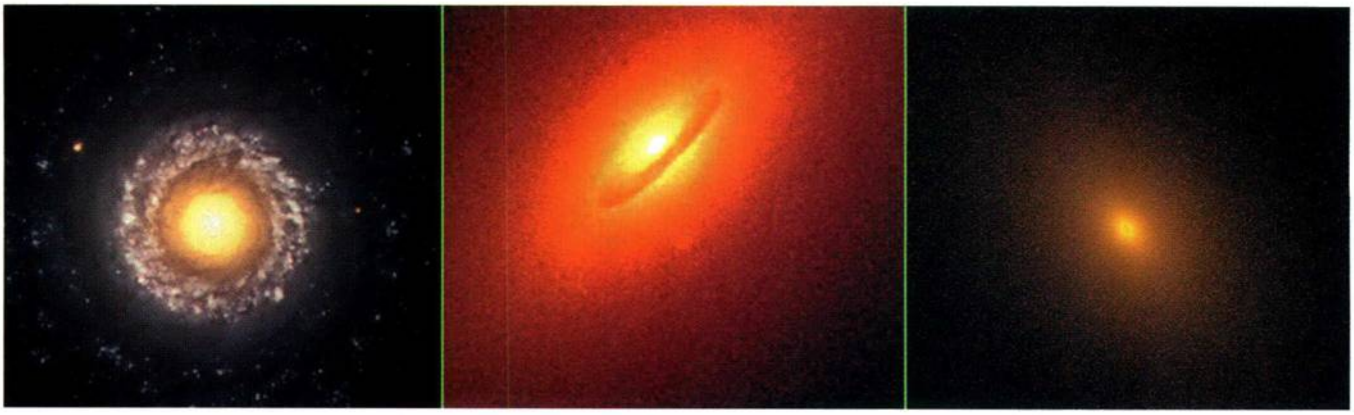
by Steve Nadis

Supermassive black holes — monsters with the mass of millions or billions of suns — are tearing at the foundations of astronomical thought, literally turning cosmological theories inside-out. And astronomers are left shaking their heads, wondering how these objects — once seen as novelty items or the stuff of science fiction — may be commonplace, dominating the core of possibly every large galaxy in the universe.

The latest results from observatories such as the Hubble Space Telescope (HST), along with the cutting-edge musings of leading theorists, are causing astronomers to reconsider the notion that supermassive black holes somehow remained divorced from the dynamic processes that gave rise to the first generations of stars, galaxies, and planets. New evidence strongly suggests a much more intimate connection than astronomers ever thought possible between galaxies and the supermassive black holes that dominate their cores.

Although supermassive black holes constitute only a small fraction (roughly 0.2%) of their host galaxy's mass, an artist's conception of an active galactic nucleus (AGN) illustrates the dramatic effects that they can produce. Andrew C. Stewart

Everywhere?



Left: A black hole likely powers the active nucleus of NGC 7742. Center: A 1.2×10^6 solar-mass black hole and a dust disk 1,200 light-years in diameter dominate the core of NGC 4697. Right: M32, companion to M31, harbors a 3.7×10^6 solar-mass black hole.

Hubble Heritage Team/AURA/STScI/NASA, Jason Pinkney/Nuker Team/NASA, T.R. Lauer/NASA.

"Previously, supermassive black holes looked like pieces of custom equipment added to a car," says University of Michigan astrophysicist Douglas Richstone. "Now they look like a standard feature. And if black holes are an integral part of galaxy formation, that could require a major revision of our theories."

Tricky Business

Given the uncertain origin of either entity, figuring out the relationship between black holes and galaxies is a tricky business. Nevertheless, theorists have posed several formation scenarios and await more data to help them decide which is most plausible. In most formation models, clouds of gas and dust collapse under the crush of gravity, giving rise to galaxies with a black hole germinating at the center.

Although significant progress has been made since the discovery of black holes lurking at the center of galaxies M87, M31, and M32 in the late 1970s and 80s, several unknowns still cloud the understanding of supermassive black hole formation. Was the gravitational collapse triggered by a smaller "seed" black hole — created during the Big Bang — which pulled in surrounding gas and dust, eventually growing into the massive giants seen today? Or did the collapse occur spontaneously, in a denser-than-average region of space, without any seed to kick it off? Did the black hole take shape in the middle of a nascent galaxy before the stars around it had a chance to form— the so-called "inside-out" scenario? Or was it the other way around — the "outside-in" scenario — with stars in the galaxy forming first and a black hole growing later, as gas, dust, and stars gradually trickle toward the galaxy center?

Throughout the 1990s HST played an instrumental role in the effort to understand the properties of supermassive black holes, uncovering such

Which Came First?

Begging the proverbial "chicken-or-egg" question, astronomers are caught in a cosmic pickle, wondering: Which came first, black holes or galaxies?

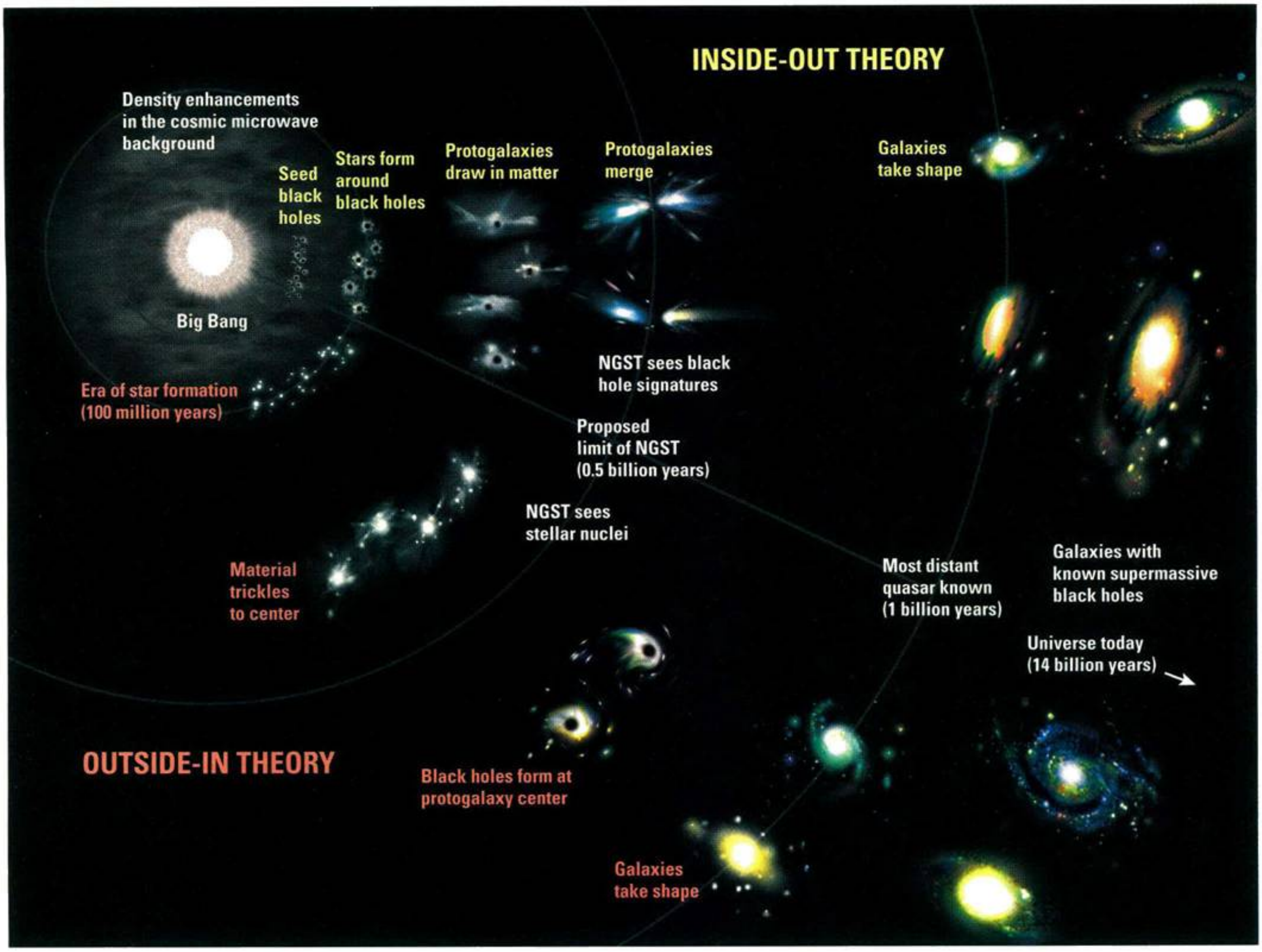
Weighing in with his answer to the puzzling question, University of Michigan astrophysicist Douglas Richstone favors the popular "inside-out" scenario, where black holes materialize first, with host galaxies later forming around them. The alternative "outside-in" scenario suggests that stars form first and migrate to protogalaxy centers to create supermassive black holes.

In support of his view, Richstone explains that in any gravitationally bound system the densest things form first. Galaxies would thus form from the "inside out," centered around a black hole. To bolster this argument, he points to systematic studies, such as the Palomar Sky Survey and the more recent Sloan Digital Sky Survey, which suggest that quasars (extremely luminous extragalactic objects that rely on supermassive black holes to produce energy) were present before most stars developed in galaxies. "If you look at this demographically, when you go farther back in time, quasars become more abundant than galaxies. And if there are quasars, there must also be black holes." — *S.N.*

Brett Littlehales

Black Hole Winds

Observational astronomers aren't investigating black holes alone. Roger Blandford, a theorist at the California Institute of Technology, is considering the effects a black hole might have on its host galaxy. If a massive black hole forms early in the life of a galaxy, he says, it could prevent the formation of a disk galaxy. That's because the energy emitted by the accreting black hole would generate a powerful "wind" that would blow surrounding material away. This outflow would carry off weakly bound gas that might otherwise have formed the disk. "So in this case, the black hole would determine the type of galaxy you have, rather than the galaxy determining the type of black hole you have," Blandford says. — *S.N.*


INSIDE-OUT THEORY
Density enhancements in the cosmic microwave background
Seed black holes
Stars form around black holes
Protogalaxies draw in matter
Protogalaxies merge
Galaxies take shape
Big Bang
Era of star formation (100 million years)
NGST sees black hole signatures
Proposed limit of NGST (0.5 billion years)
NGST sees stellar nuclei
Material trickles to center
Most distant quasar known (1 billion years)
Galaxies with known supermassive black holes
Universe today (14 billion years)
OUTSIDE-IN THEORY
Black holes form at protogalaxy center
Galaxies take shape

objects in every large galaxy that astronomers examined. A team of astronomers that includes Richstone and University of Texas black-hole sleuth John Kormendy enlisted HST to observe more than 30 galaxies with supermassive black holes. By measuring the velocities of stars as they orbit the galactic center, astronomers are able to determine the mass of the central black hole (see "Black Hole Hunters," May 1999).

Richstone, Kormendy and their colleagues found a correlation between the mass of central black holes and the mass of the host elliptical galaxies (see "0.2 Percent by Proportion," page 39). In other words, the more massive the central black hole, the more massive the host galaxy. A similar correlation has been discovered in spiral or disk galaxies between the mass of the black hole and the mass of the "bulge" — a high-density, roughly spherical clump of stars surrounding the core. What's more, pure disk galaxies, those without a bulge, seem to lack central black holes or may possess black holes that are too small to be detected through current means.

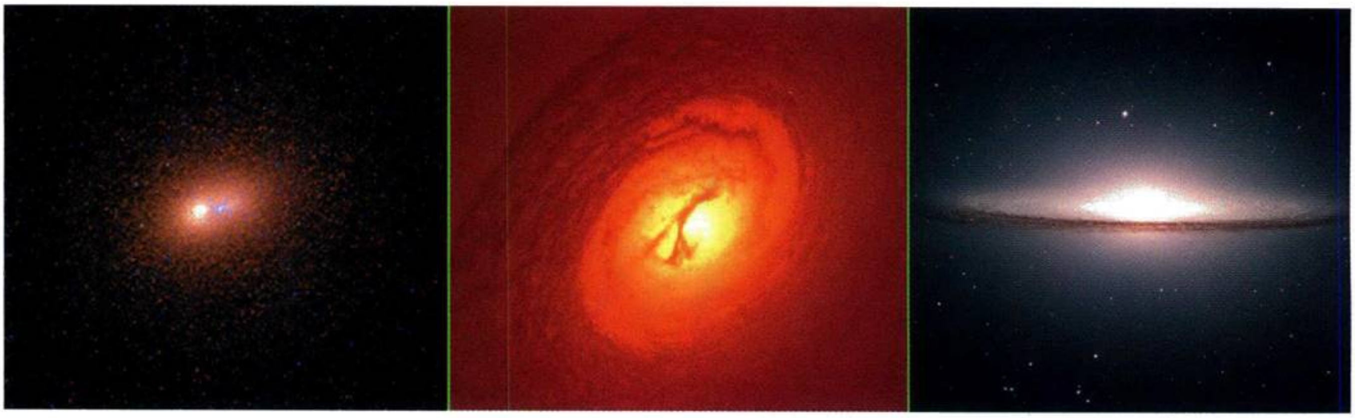
Aging Gracefully?

While astronomers attempt to sort out the mass relation between supermassive black holes and their host galaxies, the plot thickens. University of Nottingham astronomer Michael Merrifield and his colleagues recently discovered a correlation between the mass of central black holes and the age of their host galaxies. The group arrived at their conclusion after determining the ages of 23 nearby galaxies at different stages of development — by analyzing the color and intensity of starlight they emit — and comparing that to the mass of their central black holes, established by previous research.

Since the investigators couldn't monitor galaxies for billions of years, they had to take a different approach. "You wouldn't have to watch one individual over a complete lifetime to find out how people age as they get older," explains Merrifield. "One could learn a lot just by looking at a single snapshot of a large family that spans a range of ages from toddler to great-grandparent." By studying galaxies of different ages, the team showed that black holes gradually put on weight over time as they consume a steady diet of gas, dust, and stars from their hosts.

"We're measuring the time scale over which black holes grow, and it appears to be comparable to the age of the host galaxies," Merrifield says. "So they really are developing together." But this explanation still leaves open the question of the origin of supermassive black holes, which may have grown from smaller "seeds" that predate the galaxies around them. The difficulty lies in inferring the past from the patterns observed today.

Kormendy agrees that this poses a major challenge to astronomers. "The notion that black holes and galaxies grow in step seems to be correct. But we're still in the dark as to how black holes got there in the first place."



Left: The double nucleus of the Andromeda Galaxy (M31) betrays the presence of a 3.5×10^7 solar-mass black hole. Center: Astronomers hope to find a black hole in the core of NGC 3607. Right: A 1-billion solar-mass black hole lurks within the Sombrero Galaxy (M104). T.R. Lauer/NASA, STScI/NASA, VLT/ESO

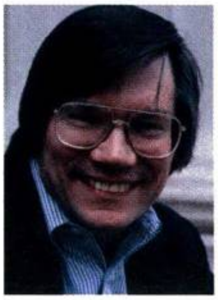
In the Beginning

Early observations of supermassive black holes confirmed the long-held belief that monster black holes were the engines powering quasars and other active galactic nuclei (AGN). But astronomers working with the Sloan Digital Sky Survey and other projects notice major problems that arise from their discovery of extremely distant quasars — some well beyond redshift five. This implies that quasars and their black-hole engines must have formed less than a billion years after the Big Bang. "But it's hard to grow a black hole very fast," Kormendy says. As matter is sucked in by a black hole, it heats up and is converted into radiation that exerts an outward pressure on other material in the vicinity (see "Black Hole Winds," page 36). "So if you dump too much stuff onto the black hole, it will just blow it away." If black holes can't grow quickly enough by conventional means, he speculates, "perhaps fairly big ones were there from the very beginning."

The current HST observing program, which aims to find a lower limit for the mass of central supermassive black holes, may point to the mass of seed black holes themselves. But where do these seeds come from? "Primordial black holes are one way to do it, but you may not need them to make this work," Richstone says. If the Microwave Anisotropy Probe (MAP) or Planck Observatory find small-scale inhomogeneities in the microwave background (see "Supernatural Solutions?," page 38), we might learn that seed black holes grew from mass density fluctuations roughly a million years after the Big Bang or earlier — long before the era of galaxy formation.

As subsequent observations favor the rising "inside-out" galaxy formation scenario (see "Which Came First?," page 36), its adversary is steadily losing steam. In fact, many astronomers, including Kormendy, find the evidence for the alternative, "outside-in" scenario less than compelling. Star clusters would have to be extremely dense for matter to trickle into the center of galaxies quickly enough to account for observations of quasars at high redshifts. But Hubble observations of distant star clusters, Kormendy says, "show that centers of galaxies are not sufficiently dense for these evolutionary processes to occur fast enough." The only way out of this dilemma, he adds, "is to assume that the centers of galaxies do not appear dense enough because the black holes ate the surrounding stars. But there is still no

Supernatural Solutions?


MIT

MIT physicist Alan Guth thinks he may have an answer to the question of how black holes formed so early, which, he says, "is very hard to understand in most versions of cosmology," including the standard inflationary model that he pioneered in 1979.

The problem lies with getting structures such as supermassive black holes to take shape in a youthful universe that appears so homogeneous. Previous glimpses of the earliest epochs of the universe show mass to be distributed smoothly, providing few clues to how matter clumped together so quickly to form black holes and galaxies. But a modified theory called "supernatural inflation," which Guth has recently developed with fellow MIT and Princeton physicist Lisa Randall, predicts mass density fluctuations within a fraction of a second of the Big Bang that steadily accreted matter, leading to the formation of "primordial" black holes within about a decade. "These black holes, in turn, might conceivably act as seeds that set the formation of galaxies into motion by steadily pulling in matter," Guth says.

There is considerable uncertainty regarding the size of these hypothetical seed black holes, which could be a million solar masses or a good deal less. The theory is still at a preliminary stage, Guth stresses, with little hard evidence to support it. So far, observations of the cosmic microwave background haven't shown a "spike" at short wavelengths that the theory predicts. But Guth says the perturbations may be observed with upcoming experiments such as the Microwave Anisotropy Probe (MAP), scheduled to launch in April 2001, or the *European Planck mission* planned for 2007. — *S.N.*

0.2 Percent by Proportion

Recent studies have shown that supermassive black holes make up roughly 0.2 percent of the mass of an elliptical galaxy or the central bulge of a spiral galaxy. But astronomers can't yet explain why this proportion seems so consistent from one galaxy to the next. They are convinced, nevertheless, that the mass correlation indicates close parallels between the development of black holes and their galaxy hosts.

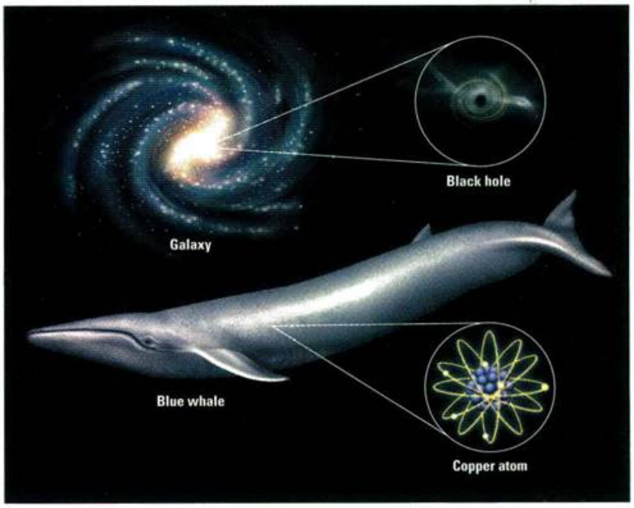
The findings make sense to University of Nottingham astronomer Michael Merrifield, who supports the currently favored picture of galaxy evolution. In this most popular scenario, small galaxies merge to form large galaxies. After two galaxies combine to form a single larger galaxy, their black holes will spiral toward the center and merge, creating a proportionately larger black hole.

But some astronomers are still puzzled by the connection. "Why, for example, is the black hole mass related to the bulge material in a spiral galaxy but not to the disk material?" asks Princeton astrophysicist Scott Tremaine, a member of the research team that discovered the mass correlation.

To explore the relation further, University of Michigan astrophysicist Douglas Richstone and his collaborators are targeting small galaxies with the Hubble Space Telescope (HST) to see if their cores might harbor low-mass (perhaps 100,000 solar-mass) black holes. But the team won't know how strong the mass correlation really is until they've looked at a large enough sample of galaxies and black holes.

Could there be a giant galaxy with a tiny black hole, one-tenth or one-hundredth the expected mass? So far, there's no solid evidence to support this. And even if such an arrangement were physically possible, University of Texas astronomer John Kormendy adds, "we couldn't detect such a small black hole with present technology because its influence on the galaxy would be minuscule." A giant black hole in a tiny galaxy — also at odds with the mass correlation — would be easier to spot, but no one has ever seen anything like that either.

Still, Kormendy is confident the mass correlation will hold up under further scrutiny. "In every galaxy we've examined, we've found a black hole with roughly the expected mass," he says. "There have been 34 successes and zero failures so far, which sounds like a correlation to me." — *S.N.*



Supermassive black holes dominate the cores of their host galaxies and may possess the mass of several billion suns, but relative to the size of an average galaxy, they are tiny objects. The Schwarzschild radius — the boundary from which light cannot escape a singularity — for an average supermassive black hole is 10 billion times smaller than the radius of an average spiral galaxy like the Milky Way. A copper atom is similarly dwarfed by the body of a blue whale.

evidence that black holes really formed in this way."

Astronomers expect the galaxy formation debate to be settled within a decade, when HST's successor, the Next Generation Space Telescope (NGST), will peer back in time, when the universe was a mere 500 million years old, to discern whether the first sources of light in the universe were quasars or stars. "The sequence of events should be obvious when we get NGST," Richstone says. "We should be able to examine protogalaxies in enough detail to see if you get a small lump in the middle first or stars first."

In the meantime, there's plenty of useful work to be done with existing instruments. "We should continue to make HST observations, looking at more extreme galaxies — those of very low luminosity or with tiny bulges — not just the galaxies we think we'll find black holes in," Princeton University astrophysicist Scott Tremaine says. "Studying galaxies over as wide a range as possible will make it easier for us to see how their properties correlate with properties of the black hole."

In addition to using HST, NGST, MAP, and Planck, astronomers will continue to observe supermassive black holes with x-ray telescopes such as Chandra to shed light on the role these dark objects play in galaxy evolution. They'll use large optical telescopes such as Keck, VLT, Gemini, and Subaru to search for increasingly ancient galaxies, as well as far-infrared and submillimeter instruments to pierce the veil of dust surrounding these stellar nurseries. And in a decade or so, LISA — a space-based gravity wave observatory — should allow astronomers to detect the gravitational signature of a merger of two supermassive black holes for the first time.

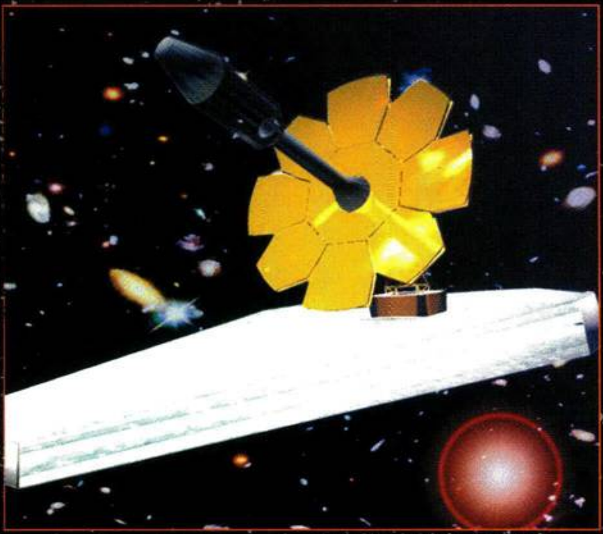
By all indications, black-hole sleuths seem to be on the right track. With the ties between black holes and galaxies still so hazy, Kormendy says, "The only way to figure this stuff out is to approach it observationally. Greek philosophers took the opposite approach. They sat around and thought and most of what they came up with was wrong. But a few actually looked at the sky, and they were the only ones who got it right." ■

Steve Nadis is a freelance writer based in Cambridge, Massachusetts. His latest article for Astronomy, *"Hunting for the Strangest Matter," appeared in the April 2000 issue.*

T

THE NEXT GENERATI
PREDICTIN

Ball Aerospace NGST Design



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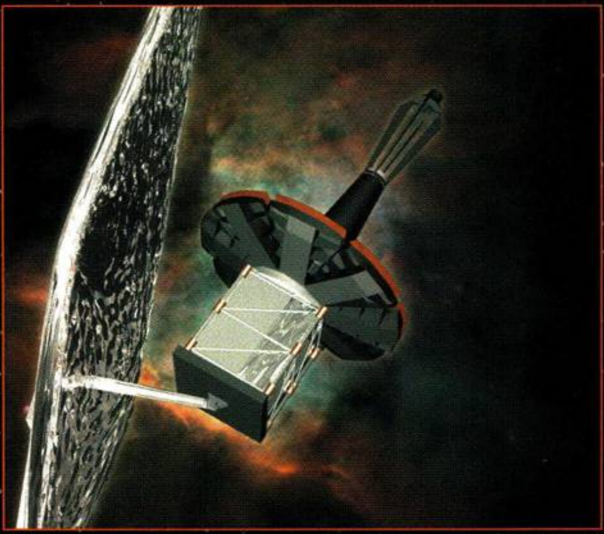

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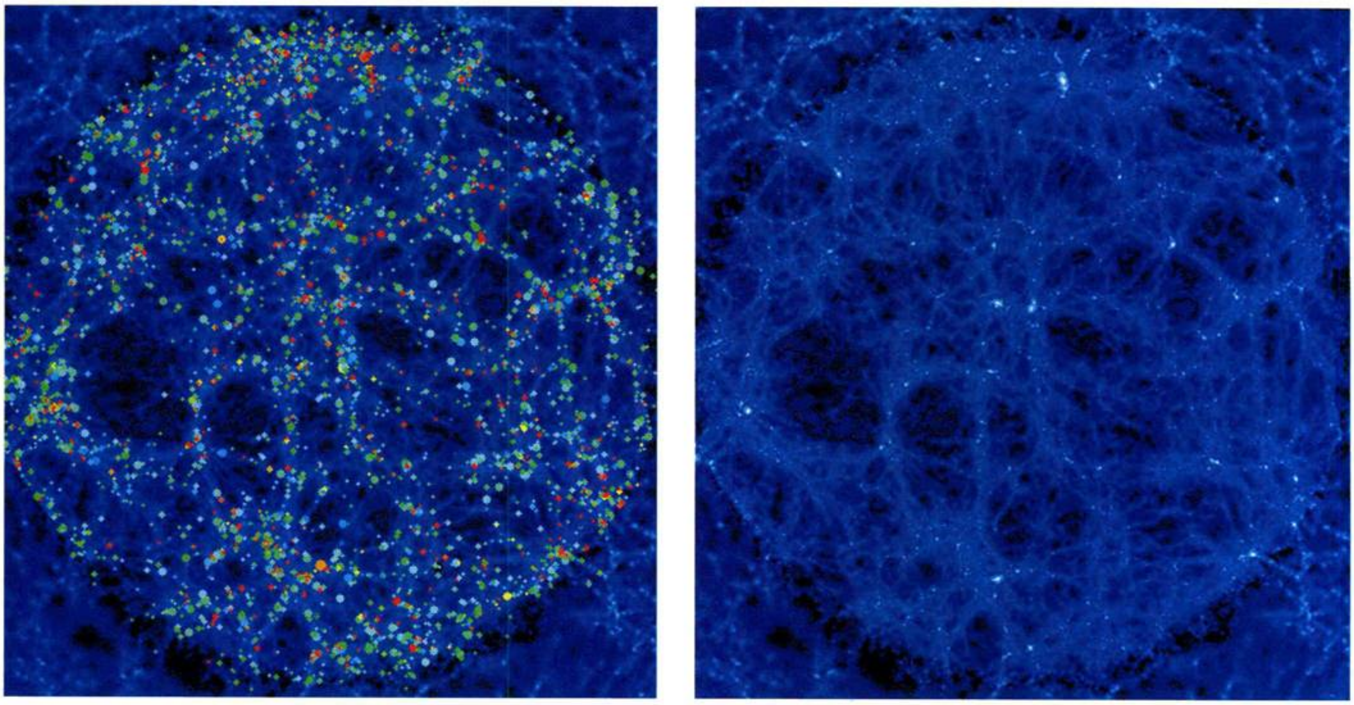
ON SPACE TELESCOPE
G THE PAST

Astronomers try to foretell what will be found by the next great scope in space.

by Marcia Bartusiak



Galaxies in the local universe form on the frothy waves of dark matter in these supercomputer simulations made by the Virgo Consortium near Munich. Max-Planck Institute for Astronomy, Garching

Princeton astrophysicist Edwin Turner knows how risky it can be to predict how the universe evolved. Twenty-one years ago he attended a conference set up to speculate on the wonders to be seen with an optical telescope launched into space, what later became the Hubble Space Telescope. The predictions, says Turner, were both surreal and irrelevant.

Hubble revealed a distant universe far more vigorous and energetic than anyone ever dreamed of two decades ago. With their space-age eyes, astronomers were able to look outward more than halfway across the visible universe. In 1979 theorists had expected nearly all the galaxies there (except for the occasional and rare quasar burning fiercely) to look pretty much the same as those around us today — the same classical spirals and ellipticals only brighter and bluer. Instead, many of the young galaxies were found to be disturbed, messy, and shaken up.

Astronomers are still trying to sort it all out. Yet, despite the flawed predictions made 21 years ago, many of the world's experts on the early universe gathered at Harvard University to once again discuss what they might find as a new generation of telescopes, both in space and on the ground, comes on-line this decade.

With these new instruments, astronomers will be reaching back to what might be called the "age of enlightenment," the era when stars and galaxies first formed. It is a key period in the universe's evolution.

Seeing the First Stars

For the first 300,000 years or so after the Big Bang, the universe was hot and bright as matter and radiation commingled. But as soon as electrons combined with protons to form atomic hydrogen and atomic helium, the radiation was released to wander for a while through the gas.

With matter cooling down and the radiation becoming dim and diffuse, the cosmos entered what Martin Rees of Cambridge University, Great Britain's Astronomer Royal, refers to as the "dark ages." These dark times didn't end and the bright times begin again until the birth of stars, their nuclear fires at last lighting up the universe with spectacular splendor.

It was the beginning of a tumultuous era: When stars are born, some also quickly die, generating supernovae that spread a star's ashes of heavier elements through the cosmos. The shock waves move through the gas to assist the formation of new stars — and at prodigious rates. Supermassive black holes begin assembling in galactic cores, turning on as brilliant quasars as they "eat" the rich supplies of primordial gas. The universe, being smaller in its youth, is also more crowded, which leads to many galaxy mergers. Perhaps that explains the strange shapes seen in the distant and thus young galaxies.

To know for sure, though, requires special eyesight. As the universe expands, the light within it gets stretched along the way — shifted toward the red end of the spectrum. Astronomers keep track with a redshift scale called "z." A z of 0 — no change at all — is the present day. A z of 1 denotes the shifted light originated at a time roughly halfway back to the Big Bang. A z of 2 is 76 percent of the way back, a z of 5 about 91 percent. (See box, page 43.) By the time the light waves emitted from the earliest galaxies have reached Earth, they have appreciably lengthened. Due to the redshift, the visible radiation emitted by the first stars has stretched into infrared wavelengths.

Hence the intense interest in the Next Generation Space Telescope, the Hubble's planned successor. It is U.S. astronomy's top priority for the coming decade. Using some kind of flexible material described at the conference as "thin as a dinner plate" (nickel, special glasses, and silicon carbide are being studied), the NGST will unfurl a mirror as much as 26 feet across. (The Hubble's more traditional mirror is just under 8 feet in width.) NGST will be designed to gather the faint infrared waves from the distant universe as far out as a redshift of 20, when the universe was a mere 200 million years old. With such power, astronomers will be able to see the dark ages come to an end and directly observe how the universe created its first luminous structures. If all goes as planned, the NGST could be up and running by 2009.

On the ground, new millimeter and submillimeter arrays will complement the exploration by gathering radio waves that can pass through intervening dust, allowing astronomers to examine young galaxies that might otherwise be obscured by their dusty envelopes. At the same time, the success of the two Keck telescopes, each with mirrors 33 feet wide, is driving enthusiasm for building ELTs, or extremely large telescopes with mirrors 100 feet or more across. Such telescopes would let astronomers carry out the sensitive spectrographic work needed to decipher the faint spectral clues arriving from the distant cosmos. Together, these varied instruments could probe the history of galaxy formation.

"Astronomy's slogan may be 'observers lead the way,'" noted Harvard astrophysicist and conference organizer Abraham Loeb in his opening remarks, "but theorists instruct them where to go." And theorists start by figuring out what the first structures in the universe might look like. Simon White, a veteran at this game for some two decades and now based at the Max Planck Institute for Astrophysics in Munich, reported on the latest results obtained by the Virgo Consortium, an international group organized to carry out supercomputer simulations of the universe's large-scale structure.

Consortium members start with a few basics. From observational evidence, they assume that most of the matter in the universe consists of a mysterious dark matter, possibly a slew of yet-to-be-discovered elementary particles known as WIMPs, for weakly interacting massive particles. Tiny density fluctuations, seen in the cosmic microwave background, cause this dark matter to start clumping. Inside the computer many eons tick away and what results over time is a spongelike structure. Through the work of gravity, the dark matter comes to be concentrated in fat threads that weave through the universe, with vast voids situated in-between.

Finding the Right Blend

More recently the Virgo team has been adding ordinary matter, the stuff of stars and galaxies, into this dark matter. This gas, as expected, eventually separates from the dark matter and begins to condense into disks. The disks merge to make spheroid bulges. The gas can even settle down around some of these bulges to make new disks. Where gas is sparse, few galaxies are made. More galaxies form in the densest regions. In this way, Virgo team members try to duplicate what is seen in the present-day universe. "We get a rough fit," said White.

In one particular simulation, they even had clusters of galaxies that look very much like the prominent clusters near us today, such as the Coma, Virgo, and Centaurus clusters. Moreover, these simulated clusters were seen to form fairly early, matching what observations suggest. Using the Keck telescopes, Caltech astronomer Charles Steidel has been reaching farther and farther out into the universe, out to a redshift of 5. Already at a z of 2.5 to 3.5 he sees indications of strong galaxy clustering. There are already hints that high redshift quasars, too, are predominantly arranged in large structures. The Sloan Digital Sky Survey, now mapping the celestial sky with a dedicated 2.5-meter telescope at Apache Point Observatory in the Sacramento Mountains of New Mexico, is discovering dozens of new quasars. The farthest ones are strongly clustered.

Such successes give theorists the courage to speculate on other questions. How did stars first form within those primordial structures built out of dark matter? When did star formation get started? How did it then evolve, and were those early stars similar to the ones being made today, say in the Orion Nebula?

For the moment, theory suggests those first stars had to be different. For one, they would be burning pure hydrogen and helium. The heavier elements were not yet cooked up. Such conditions tell theorists that the first stars had to be heftier than the average star today, since the hotter core of a massive star may be required to carry out nuclear fusion with hydrogen and helium alone. Each star might contain the mass of a hundred or more of our suns. Such stars would live and die relatively quickly, a few million years or so, and emit copious amounts of ultraviolet radiation.

According to some current theoretical models, the first stars would begin to condense once there were dark-matter clumps in the universe weighing at least a million solar masses, the sorts of objects the Virgo consortium sees in its simulations. Such a clump produces a big enough gravitational "well" for the primordial hydrogen and helium dispersed throughout the dark matter like an added spice (about 100,000 solar masses) to be attracted inward and begin to cool to form star-sized objects.

Tom Abel, an astrophysicist at the Harvard-Smithsonian Center for Astrophysics, took conferees on a tour of the birthing process with a computer simulation that he had conducted with his collaborators Greg Bryan of MIT and Michael Norman of the University of Illinois. Starting with a uniform mix of primordial dark matter and gas, they followed its gravitational collapse over time. By a redshift of 20 or 30, about 100 million years after the Big Bang, the first star is born.

Step by step, Abel zoomed in to display the inner structure of a dark-matter clump. At a range of 2,000 light-years, a sort of protogalaxy is observed. The gas by now has fallen

How Far to the Big Bang?

Redshift	Dis. from BB	% of Dist.	Distance
0	13.5 billion ly	0	0 ly
0.5	8.4 billion	37	5.1 billion
1	5.8 billion	57	7.7 billion
2	3.2 billion	76	10.3 billion
3	2.1 billion	84	11.4 billion
5	1.2 billion	91	12.3 billion
7	750 million	94	12.7 billion
10	465 million	97	13 billion
15	265 million	98	13.2 billion
20	177 million	99	13.3 billion
infinity	0	100	13.5 billion

These numbers can vary depending on the cosmological model and parameters chosen. This table was calculated assuming that the Hubble constant is 70 km/sec/Megaparsec and that the universe is right on the border between open and closed, with matter contributing a third of the critical density and a cosmological constant making up the rest.

inward and settled into the center, surrounded by the halo of dark matter. Zooming inward to a scale of 200 light-years, a dense cloud is detected in the center.

Going further down to a range of two light-years, an even denser core is observed with temperatures rising to 1,000° kelvin. It contains some 200 solar masses. In the center of this core, spread over a region the width of seven solar systems, is a protostellar disk of material that will become the "first star." The innermost part contains one solar mass of material but with a gaseous envelope of 100 solar masses that may continue to accrete.

The simulation suggests that only one primordial star can form at first in any single dark-matter halo. The star's fierce ultraviolet radiation inhibits the formation of any other stars in the cloud. "Any other star that wants to form," says Abel, "may have to wait until the first one dies. That is one of the interesting results from the simulations." But is that realistic? "We're far from figuring out star formation," cautioned Princeton's Turner. The simulations so far depict a relatively gentle infalling of gas.

"We see here in the Milky Way that it's a messy process," notes Turner. And so many questions are still left unanswered. Since the gas heats up as it falls inward, how does the protostar continue to cool and condense to make the final star? It's partly done as the individual hydrogen atoms join to form molecular hydrogen, which allows some heat to be released. But how this cooling continues as the protostar turns into a star is not yet fully understood.

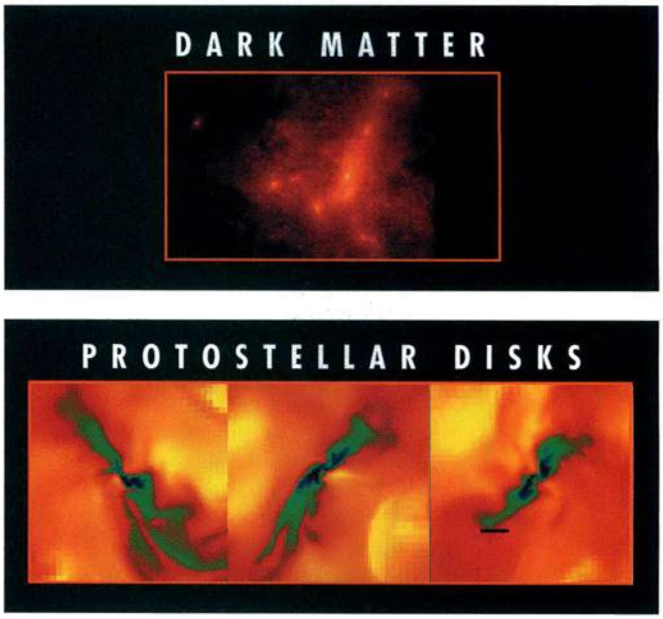
Simulating the First Stars

Volker Bromm at Yale has also carried out simulations of a primordial star's birth. He arrived at the conclusion that the first stars might have been very massive indeed, possibly as many as 1,000 solar masses. Could some of them have been the seeds, he asked, for the supermassive black holes found in quasars later on? Jerry Ostriker of Princeton estimates that the Milky Way contains some 10 million stars from that first epoch of star formation, stars with low enough masses to not blow up but rather slowly simmer over the eons. Their positions would trace the primordial halo of our galaxy. "This makes them worth looking for," says Ostriker.

The first stars were initially surrounded by neutral hydrogen, a gas that is opaque to ultraviolet light, the primary radiation emitted by massive newborn stars. In other words, the ultraviolet radiation couldn't get through. It was continually absorbed by the hydrogen, which thus acted as a screen to prevent us from observing this era. But the birth of stars marked a dramatic transition for the universe. Their very presence drastically alters the cosmic environment.

Once a star forms, it begins to ionize the hydrogen surrounding it. The star's intense radiation strips off the hydrogen's electron. This is an important process in the universe's history. Once the hydrogen is ionized, it is no longer a barrier to ultraviolet radiation. The photons can fly through such a medium freely. In this way the universe becomes open for inspection. Astronomers call it the "epoch of reionization." (It's called "reionization" because the early universe, before the dark ages began, had once before been hot and ionized.)

When *did* this begin? Examining the spectra of the farthest known quasars, around a redshift of 6, astronomers can tell that the universe was already highly ionized by that time. So, the process had to begin earlier. But not too early: Reionization couldn't have started before a redshift of 30, for example, because that would have diminished the fluctuations seen in the cosmic microwave background. Nickolay Gnedin of the University of Colorado believes reionization may have begun in earnest around a redshift of 15.



Harvard astrophysicist Tom Abel's computer simulations of the first stars investigate how dark matter clumps into disks. Tom Abel/Harvard

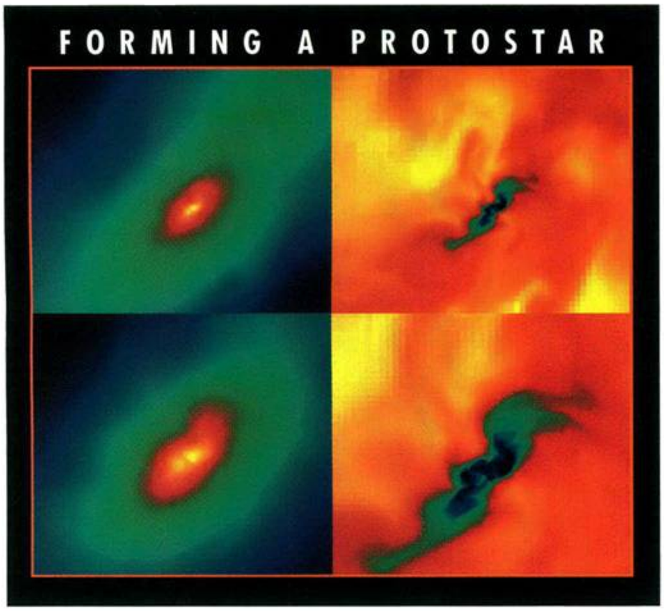
And what happens at that point is a fascinating tale. A computer-generated movie that Gnedin produced showed the process in beautiful detail. (It can be seen at http://casa.colorado.edu/~gnedin/gallery.html.) He started with a slice of the universe some 20 million light-years across. Stars are born and begin to heat up the neutral hydrogen, creating bubbles of ionized hydrogen around the star-bursting protogalaxies.

A patchwork of bubbles peppers the screen, resembling a slice of Swiss cheese. Over time, though, these pockets of ionization gradually expand throughout intergalactic space, until they merge with neighboring ones. What results is a universe suddenly clear of obscuring neutral gas.

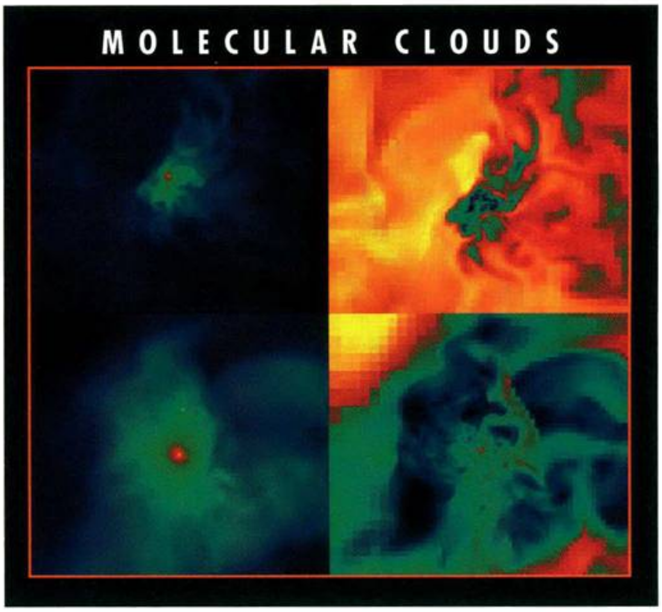
The merger of the bubbles is a very abrupt and dramatic transition. Astronomers call it the "ionization breakthrough." In Gnedin's simulation, it occurs around a redshift of 7. The entire process — from first reionization to final breakthrough — may take a relatively short time, as cosmic events go. Theorists estimate several hundred million years or so. "If the universe is a 50-year-old person," suggests Gnedin, "then reionization took place when he or she was two years old and lasted for two months." Quasars, with their intense energies, probably helped the ionization along, but these theorists believe the bulk of the work was done by stars.

With the right instrumentation, astronomers have a chance of observing the epoch of reionization directly. While ultraviolet radiation is blocked by neutral hydrogen gas, radio waves are not. If radio waves can be gathered from that distant era, astronomers will be able to witness the ionization bubbles growing and connecting.

Such an observation would be a tour de force. It would be like discerning a whisper from across the hall at an overamplified rock concert. Strong local signals, like the many



Abel next creates a look at how the first stars might have gravitationally collapsed at the centers of these disks.



Though he can simulate them by supercomputer, the first stars may only be seen in the echos of ancient molecular clouds.

radio waves here in our own Milky Way Galaxy, would first have to be filtered out. To accomplish such a feat will require a radio telescope whose total collecting area is one square kilometer. Such a detector — called appropriately enough the Square Kilometer Array — has already been proposed and is now under study by an international consortium of astronomers.

At the moment the participants are discussing having anywhere from 100 to 1,000 separate antennae. As many as half of them might be set within 30 miles of one another in a remote area, such as the U.S. southwest or western Australia; the rest could be scattered over hundreds of miles or even over the globe. But collectively they would act as one huge telescope.

The Future of Stars Past

Harvey Butcher of the Netherlands Foundation for Research in Astronomy reported that such an array would have a hundred times the sensitivity of current radio telescopes like the Very Large Array in New Mexico or the Arecibo Observatory in Puerto Rico. "The sky would change dramatically," said Butcher. It would allow astronomers to see the first structures in the cosmos form and evolve, as well as observe star formation over the entire history of the universe.

Once star formation is underway — with stars actively cooking up the heavier elements in their interiors — a galaxy can get quite dusty. Dust particles, microscopic grains of such elements as carbon and silicon spewed into space upon a star's death, can rapidly obscure a galaxy. Its radiation is absorbed by the dust and then re-radiated at longer wavelengths. Most of this light from distant, dusty galaxies can be redshifted into the submillimeter region.

Hence, theorists are greatly interested in the new instruments about to turn on to explore this region, such as the Submillimeter Array on Hawaii's Mauna Kea. This array consists of eight dishes spread over a third of a mile. But that's only the start. A U.S.-European collaboration is planning to build the Atacama Large Millimeter Array (ALMA) on a high plateau in the Andes Mountains of Chile. ALMA might have up to 64 dish antennae dispersed over a six-mile-wide area.

A smaller detector called SCUBA (for submillimeter common-user bolometer array) working on the James Clerk Maxwell telescope at Mauna Kea already has imaged distant objects that resemble the ultraluminous infrared galaxies seen here in our local galactic neighborhood. These nearby "ULIGs" usually turn out to be galaxies merging. This generates huge bursts of star formation, hundreds of times greater than the Milky Way's production rate. If the SCUBA objects are ULIGs, this opens up the possibility that a substantial fraction of the star formation in the distant universe could be hidden by dust.

But SCUBA offers only a coarse picture. The distant objects seen in the submillimeter region might also be active galactic nuclei. The Submillimeter Array would sharpen the image and help decide what is truly happening in the far universe, perhaps as far out as a redshift of 10. Until then, theorists can only guess.

One month before the launch of the Hubble Space Telescope in 1990, a group of astronomers was asked to imagine what might be seen in the telescope's longest exposure, the type of picture that was eventually made and called the Hubble Deep Field. The astronomers at the time carried out a simulation, based on their best working knowledge of how the early universe behaved.

The picture they produced was fairly bland. Their distant galaxies were dim and sparse. The real Hubble Deep Field, on the other hand, turned out to be chockablock with colorful objects, large and small, pale and bright. "That should give us pause," said Edwin Turner at the end of the conference. "People ten years from now may find our predictions just as quaint."

Marcia Bartusiak is an accomplished science writer and member of Astronomy's *editorial advisory board. Her latest article was "Astronomy Careers Beckon," November 2000.*

PRIMETIME

Research time on a big telescope is the most precious commodity in astronomy — and the most difficult to parcel out.

by Robert Irion

IMAGINE THAT YOUR NEIGHBORHOOD ASSOCIATION BUYS A SMALL telescope. Your kids can't wait to see craters on the moon and the rings of Saturn. But when you step outside on the first clear night, dozens of people have the same idea. A sign-up sheet fails when greedy families hog the best slots. Soon you're forced to apply to the association for observing time — and you're lucky to get an hour or two each month.

Professional astronomers face that same situation, but with stakes far higher than peeking at a pretty planet. Stargazing time at research observatories is in such heavy demand that scientists compete fiercely for slots. No official roster dictates who's in and who's out; no automated system spits out a neat syllabus. Rather, astronomers rely on each other's judgment to weigh one proposal against the next.

Decisions about who gets time on big telescopes can make or break careers as well as lead to major discoveries that influence the course of

Car taillights snake toward Gemini North Observatory as star trails whoosh through the sky in this time exposure. Gemini Observatory and the National Science Foundation

astronomy. "The process of time allocation is one of the most critical functions for the astronomical community," says David De Young, who chairs time-granting panels at the National Optical Astronomy Observatories (NOAO) in Tucson, Arizona.

Committees meet once or twice a year at each observatory to consider dozens or even hundreds of proposals. The committees produce ranked lists, based largely on the scientific merit of the projects and their suitability for particular telescopes. Panels assign blocks of time to each project in order of priority until the time runs out. Far more proposals fail than succeed, especially at prominent facilities.

This process, called "peer review," is laborious and even agonizing, astronomers say. It often requires granting time to rivals and spurning the requests of friends. Further, panels must compare strengths and weaknesses among diverse projects, with no firm guidelines for determining which pursuit is worthier.

"It's an almost impossible job," says Joseph Miller of the University of California (U.C.), Santa Cruz, who assigns telescope time to U.C. astronomers at the W.M. Keck Observatory on Mauna Kea, near Kamuela, Hawaii. "How do you say that observing volcanoes on Io is less important than measuring the expansion of the universe? It's like grading apples, oranges, bananas, and pears, and saying which is the best of those. You really can't."

Yet astronomers must do it all the time, or anarchy would reign. *Astronomy* examined the time-allocation process at three leading organizations: NOAO, the Keck Observatory, and the Space Telescope Science Institute (STScI) in Baltimore, Maryland — home base for the Hubble Space Telescope. While there are differences, the bottom line is clear: "It's based on the merit of the proposal and the quality of the scientific ideas," says NOAO director Sidney Wolff. "That's it."

A NATIONAL JURY

Any astronomer in the country can apply to NOAO, which oversees numerous telescopes funded by the National Science Foundation. Main facilities are the Kitt Peak National Observatory in Arizona and the Cerro Tololo Inter-American Observatory in Chile, each of which has a four-meter telescope and several smaller ones. NOAO grants access to the half-time U.S. share of the eight-meter Gemini North telescope on Mauna Kea.

Seven panels of astronomers, each with five or six members, meet twice a year to consider NOAO time requests. Administrators recruit senior and junior astronomers who are well-versed in their fields and known for high ethical standards to serve on the two-year panel. That's a major time commitment, but astronomers view it as a civic duty. "Most folks respond to our appeal," De Young says.

Three panels focus on research within our galaxy, three on research beyond the Milky Way, and one on solar system studies. Panel members read 50 to 100 proposals and submit initial recommendations in advance. Additionally, the panel chair assigns each proposal to a "key reviewer" who assumes responsibility for an in-depth study of its scientific merit.

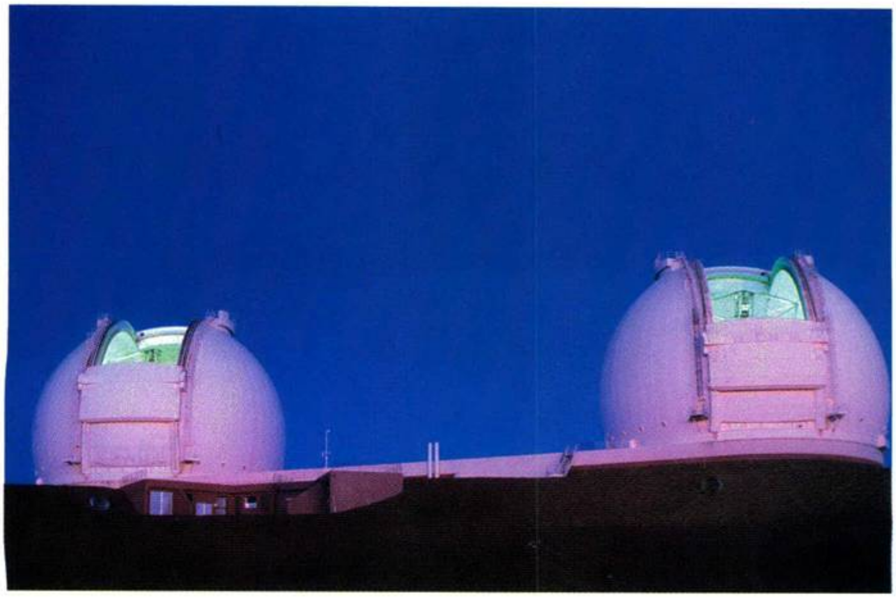
Panelists then convene in Tucson for two intense days to hash out their marks. Few decisions are easy, says Richard Griffiths of Carnegie Mellon University in Pittsburgh, Pennsylvania. "There are a minority of excellent proposals that everyone agrees have to be done, and there are some awful proposals," he says. "But the majority are in the middle." In order to make the cut, Griffiths says, "Someone has to champion it."

Biases sometimes creep in, says NOAO panelist Raja Guhathakurta of U.C. Santa Cruz. "You invariably know some people and their projects better than others," he says. However, a more powerful factor usually counters that pitfall: clarity. "A good proposal must explain succinctly why the scientific goals are important," Guhathakurta says. Griffiths concurs: "If everything is clear and well written, then it's going to get a high grade." Proposals that wander off track or lapse into excruciating detail get spiked, he says.

There are other routes onto NOAO telescopes. In 1999, Wolff instituted a program in which a special peer-review panel allocates 20 percent of the observing time for large survey projects that require many nights over long periods. Another 20 percent is allotted for the ground-based programs that use data from one of three observatories in space: Hubble, the Chandra X-Ray Observatory, or the Space Infrared Telescope Facility, set for launch next year.

In the end, only about one in four proposals survives for the premium slots at NOAO — dark nights (shortly before and after the new moon) on the largest telescopes. At Gemini North, which just began operating this year, the ratio is worse: Only about one in six gets approved. "It's painful for the committees," says De Young. "They always feel that they're turning away meritorious science."

Indeed, all astronomers interviewed noted that there is no clean line between winning and losing. Although panelists try to rank the originality, scientific implications, and technical feasibility of each proposal, it boils



Keck Observatory's twin domes on Mauna Kea glow at sunset, awash in the pastel colors of twilight. Andrew Perala

Scientists Mark Kochte, Helen Harte, and Lloyd Rawley monitor Hubble data before passing it on to an electronic archive. Quality control of HST's observing time and data storage requires a coordinated effort between the Space Telescope Science Institute in Baltimore and the Goddard Space Flight Center in Greenbelt, Maryland. John Dean/STScI

down to the tastes of a few people with unique opinions about how the field should progress. "You can put a proposal in to Kitt Peak and get a very low grade, and put the same proposal in the next year and get a very high grade," says Griffiths.

Still, applicants who don't make the cut rarely complain, De Young notes. That's because most astronomers serve on national time-allocation committees at some point during their careers, so they see the process from both sides. NOAO also takes pains to publicize its procedures and the identities of its panelists. "We try to make it, both in actuality and in perception, as scrupulously fair as we can," says De Young. "There's no feeling of a closed, smoke-filled room where guys get together and divvy up the resources."

TIGHT ACCESS AT KECK

The process is more closed at the Keck Observatory, but that's not because of secrecy: Keck is privately owned. Time on its twin 10-meter telescopes is available only through the institutions that built and operate Keck atop Mauna Kea.

The University of California and the California Institute of Technology share access to 30 percent of the time at the two Keck Telescopes. The University of Hawaii, which owns the site, accounts for 15 percent. The only publicly accessible time goes to NASA, which bought a 15 percent share of the observatory for astronomers who study the origins and evolution of planetary systems. The final 10 percent is reserved for engineering tests of the telescopes' complex mechanisms.

Time-allocation committees at U.C. and Caltech meet twice yearly, but operate differently. At U.C., an 11-member panel represents astronomers at the university's eight general campuses. Panelists grade proposals in advance and then meet as a group. Director Joseph Miller reserves some nights for astronomers who have designed instruments for the telescopes. Miller is sympathetic to young faculty, especially if they get unlucky with a few cloudy sessions. "This is a twiddling of the schedule," he says. "I must have valid reasons to deviate from the advice of ten good scientists." Proposal success ratios vary from one in two when the moon is up to one in four for dark nights.

At Caltech, five astronomers meet biannually to allocate time to their colleagues. Both faculty and postdoctoral researchers may apply for nights at Keck, whereas U.C. limits its process to faculty only. (Graduate students and other applicants must list a faculty member as principal investigator.) Caltech's smaller community enjoys unparalleled access to Keck. A typical Caltech astronomer might get 12 to 15 nights per year, compared to four or five nights for most U.C. astronomers. Those with demanding and well-funded observational programs could see 20 to 25 nights.

In this way, Caltech's astronomers come close to following the old model of astronomy research from the mid-20th century, Miller says. "At Palomar and Lick observatories during their most productive years, astronomers were getting 25 to 30 nights per year. That era is long gone," he says. Oversubscription at the major facilities poses severe dilemmas. "You see many excellent proposals not getting the time they deserve, and careers get affected," Miller laments.

Keck's close, familial setting often makes the time-allocation process even more wrenching and increases tension, says Wallace Sargent of Caltech, past director of Palomar Observatory. "We try to achieve objectivity by circulating people on the committee according to field," he says. "But it's very hard to avoid conflicts of interest." Scientists must leave the room when committee members discuss their proposals, Sargent notes. Even so, he says, "It's hard to judge one's friends and even harder to judge one's enemies. It cannot be a totally objective procedure."

A particular challenge, Sargent observes, is that astronomers at Caltech and on all other time-granting panels must account for the scientific ability and productivity of each proposer. Committees require proof of how astronomers made good use of time awarded in the past. "Two people can write identical proposals, but one will obtain brilliant results while the other will screw around," he says. "That's harder to quantify."

Even if faults exist, Sargent believes that the mixture of public and private observatories in the U.S. serves as a great equalizer. Each facility has its own review committee, so an approach that falls flat at one may meet with acclaim at another. "In Europe, the system is much more centralized: One committee decides everything," Sargent says. "The element of randomness in our process is extremely good for science."

THE DEMANDS ON HUBBLE

The ultimate time-allocation process occurs each autumn in Baltimore as astronomers gather at the STScI to plan Hubble's year. "It's the most important committee in astronomy," says Michael Shara of the American Museum of Natural History in New York, who chaired the STScI committee for three years. "Hubble has the biggest impact. It determines the direction of astronomy for the next couple of years in many ways."

The process for vetting proposals to observe with Hubble evolved over the telescope's 10-year lifetime. It's a process that continues today. As recently as 1998, experts on 17 panels reviewed proposals in their narrowly defined specialties, such as supernovae or the interstellar medium. That led to some problems. "They focused on minutiae and had less interesting scientific discussions," says Meg Urry, head of the Science Program Selection Office at STScI. Two years ago, there were nine general panels with eight members each. Then panel leaders joined the chair of the overall committee, Alan Dressler of the Carnegie Institution of Washington, to choose a few ambitious proposals that needed major chunks of Hubble's time to succeed.

"It's good to change the process every year," Shara comments. "Otherwise, people play games with the proposal process to try to maximize their chances." As it is, most astronomers don't expect a winning Hubble hand. Of roughly 1,000 proposals received each year, fewer than one in six succeed. A critical deciding factor is whether Hubble is the best — and only — tool for the job. "The observing program has to be unique to HST and make the most efficient use of its time," says Dressler.

Panel members for HST dole out "orbits" rather than nights. Hubble circles Earth once every 90 minutes; about half of that time is usable for observations. A single orbit suffices for some observations, although most require more time. One of the telescope's most famous studies, the Hubble Deep Field photograph of extremely distant galaxies near the Big Dipper, took a whopping 150 orbits (about 10 days) to complete in 1995. A similar survey examined a tiny part of the Southern Hemisphere sky in 1998. Time for those orbits was granted not through a review panel, but by the STScI director at the time, Robert Williams. This "discretionary time" — about 10 percent of Hubble's total observing time — lets the director reward proposals that review panels might find too daring.

Expect to see more ambitious programs now that Hubble has completed its benchmark studies. "After 10 years, there is a desire to push the envelope," says STScI astronomer Ronald Gilliland. In 1998 Gilliland won approval for an eight-day, 120-orbit study of thousands of stars in the globular cluster 47 Tucanae. His team's goal was to search for Jupiter-size planets in tight orbits by detecting periodic dimmings in starlight as the planets crossed in front of their stars, but Hubble spotted no planets. This negative result may mean that some fundamental property of globular clusters interferes with planet formation.

Shara hopes to see proposals on Hubble that earn allocations of hundreds of orbits — or even more. "No one has yet had the temerity to ask for a thousand orbits, but I suspect they will in the waning years of the telescope," he says. "It will be the best way of attaining a major breakthrough."

THE BEST SYSTEM?

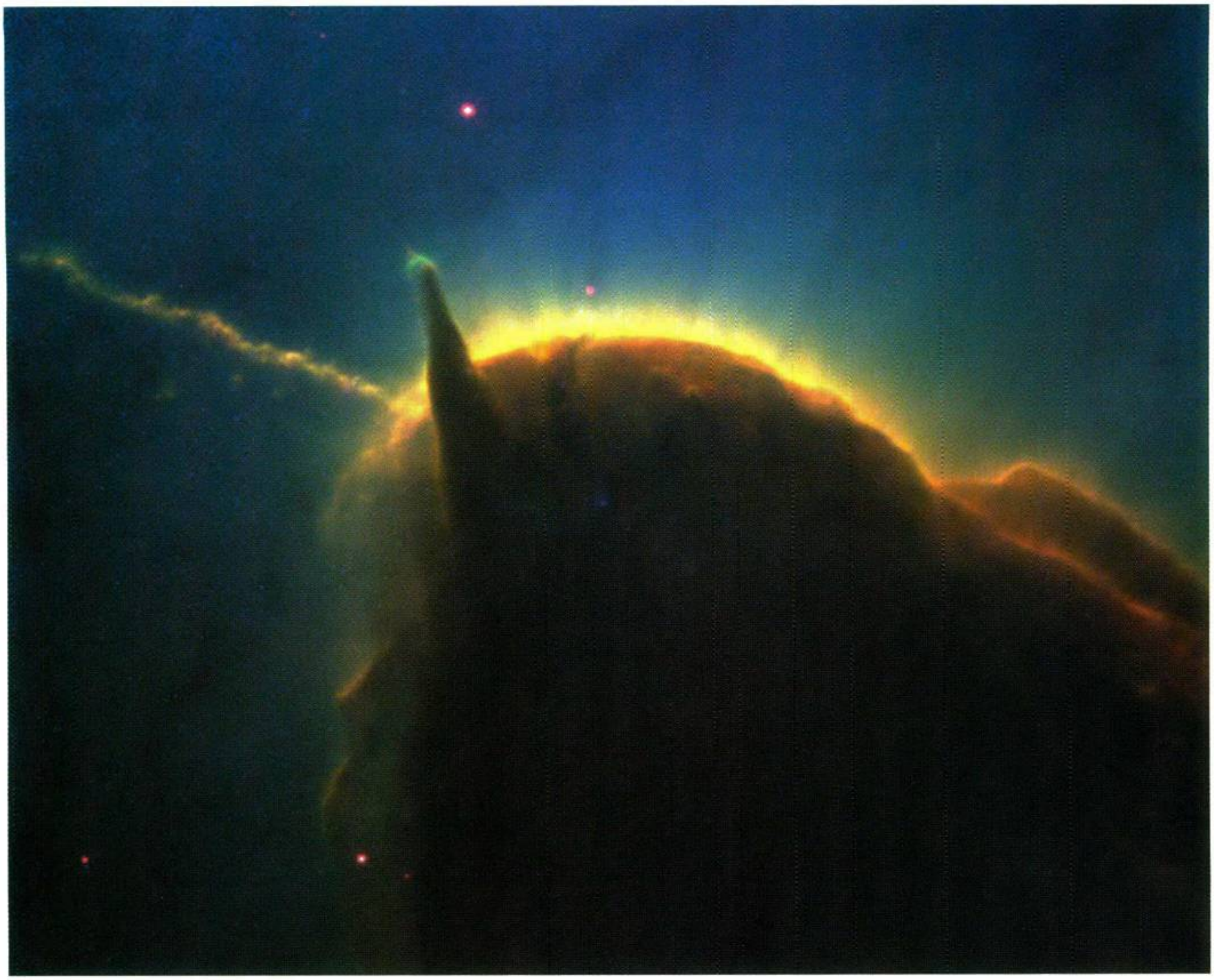
Such an initiative would take a bold stroke by astronomers. It also would go against the natural caution inherent in the peer-review system. "Scientists tend to play their cards very straight," says

Bad Weather? Tough Luck

Pity the astronomer who waits six months for two precious nights of observing time on a big telescope in Hawaii, only to see clouds roll in before the dome ever opens. Weather is astronomy's wild card, and it forces many astronomers to deal the same hand to the next time-allocation committee and hope for the best.

For the most part, committees do not consider previous weather problems when ranking a new set of proposals. "Our policy is that it's just bad luck, and everybody gets their share of it," says Joseph Miller of U.C. Santa Cruz. However, he notes, if many cloudy sessions start to hinder an astronomer's progress, the review panel may put the next proposal on the fast track.

Kitt Peak director Richard Green notes other situations where clouds may alter a committee's deliberations. "A graduate student trying to complete thesis observations or a team that is just one night away from finishing an important project may be treated with some extra kindness," he says. "On the other hand, a topic that appeared exciting and timely one year may be thoroughly explored by successful observations at other facilities before the committee reconsiders the original proposal." In that case, astronomers have to come up with something new — and hope the rain stays away next time.



It took astronomers several sessions on Hubble to capture this stunning image of the Trifid Nebula. Jeff Hester, Arizona State University/NASA

Terry Oswalt of the Florida Institute of Technology, program director for stellar astronomy and astrophysics at the National Science Foundation. "We tend to be conservative, both in writing proposals and in judging them."

Former Kitt Peak director Geoffrey Burbidge of U.C. San Diego, a longtime critic of peer review, is more blunt: "There's a shortage of facilities, and people believe that the best way to have a successful career is by conforming. Peer-review committees approve what they are doing themselves and what they think is safe. Young astronomers think that if they propose anything really different, they'll get shot down."

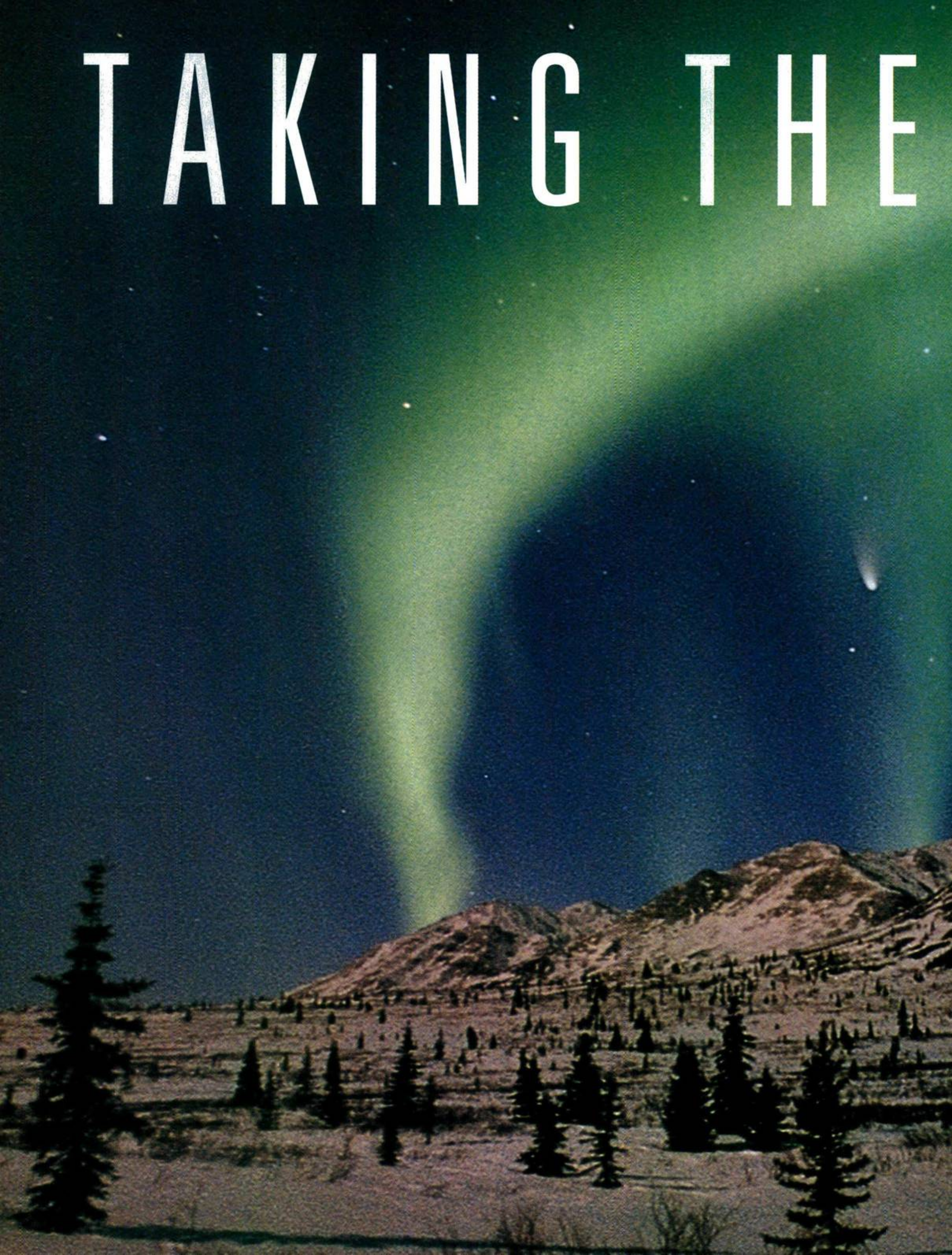
Burbidge criticizes the "bandwagon effect" over trendy observations. Astronomers flock too quickly to popular interpretations of hot topics, he says. For example, scientists may tailor proposals to observe gamma-ray bursts to support an emerging notion that they arise from the collapses of gigantic stars into black holes, rather than remaining open to other possibilities. The biggest bandwagon of all, Burbidge asserts, is the Big Bang scenario for the birth of the universe. Those who dare to propose observations that might undermine the big bang are "damned," he says, and put their careers in jeopardy.

Few agree with Burbidge that the time-allocation process is so inflexible. Indeed, the directors of NOAO, Keck, and STScI assert that speculative proposals have their place in astronomy today — if researchers put them forth in a rigorous scientific manner. Current STScI director Steven Beckwith encouraged more risky ideas for Hubble's observations in 2001–2. "We have to do exploratory things with our big facilities to keep the science vital," Beckwith says. "Every once in a while we discover something completely radical, something that we weren't clever enough to predict."

Yet if conservatism is a flaw of the time-allocation process, it seems one that astronomers have accepted for now. "The community itself came up with this process," says Edwin Turner of Princeton University, former chair of the Space Telescope Science Institute Council. "It was not forced upon us by an act of Congress. It's not that we feel it's perfect, or that we never make mistakes, or that we're always happy with the outcome. It's just that no one has any better idea." ◼

Contributing editor Robert Irion, coauthor of One Universe: At Home in the Cosmos *(Joseph Henry Press, 2000), has never applied for observing time on a telescope. His latest feature for* Astronomy *was "Raising Lunar Prospects" in the February 2000 issue.*

TAKING THE



HIGH ROAD

One amateur astronomer shows how a trip to a mountaintop can bring rewards of elusive observing delights.

by Ken Hewitt-White

MID-SEPTEMBER. NIGHTFALL. JAW AGAPE, I'm staring upward, entranced once again with the spectacle of wall-to-wall stars. I embrace the virgin darkness and the silence. Well, near-silence. Two owls are hooting in the evergreens that slope steeply away from me, and I can just make out the dissipated roar of an 18-wheeler 1,500 feet below — a trucker on his midnight run through the mountain pass.

Like the trucker, I'm on a solo run too. But mine takes me past the Milky Way, out to the galaxies and back. For most of my adult life I've been compelled to seek out alpine observing sites to satisfy my undying love for deep-sky objects. The professionals who travel to Hawaii and Chile know that there are advantages to high-elevation astronomy. It's no different for the amateur. The mountains are where I go to make contact with the cosmos.

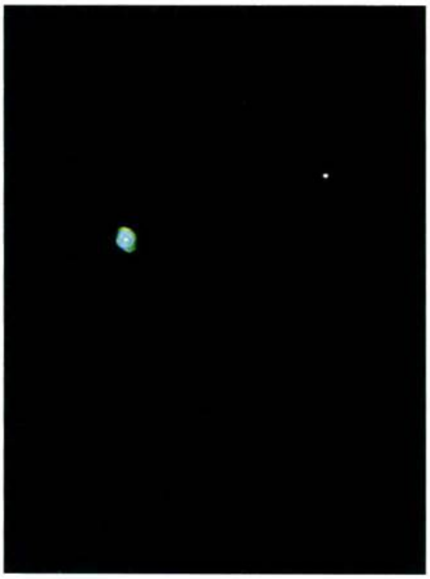
Normally the only light pollution at high mountain elevations comes from the moon or aurorae. Michael Klensch

My astronomical outpost is, by day, a tourist attraction known as the Cascade Lookout. It protrudes from the south face of Blackwall Mountain in Manning Provincial Park, 100 miles inland from Vancouver, British Columbia. Blackwall's narrow, twisting access road climbs through dense forest before breaking clear halfway up the mountain. There, from nearly 5,200 feet, the view boasts an eye-popping spread of snow-capped peaks straddling the 49th parallel.

CROWNING GLORY: THE SWAN

At night, a confined dome of pale light due west pinpoints British Columbia's largest city. Hugging the southwest horizon is the barely perceptible signature of Seattle, Washington, 125 miles away. Below the lookout, the park maintains a lodge and cabins, but the accompanying lights are hidden from sight. The sky here is truly dark.

I arrive around sunset and assemble my 10-inch and 17.5-inch Dobsonian telescopes a few paces from my camper van. I swing open the rear doors and prop up my charts inside, safe from wind or dew. My deep-sky hit list, prepared earlier that day, goes on a clipboard that hangs on one door. Oculars are arranged, small to large, on a shelf under the bed. A mini-tape recorder lashed to the finder of the larger scope allows me to record impressions right at the eyepiece. Everything is geared for efficient movement between scopes and accessories.



The Cat's Eye Nebula holds observing surprises for those at exquisite sites. Ronald Royer

Fashion-challenged clothing goes on in layers as the evening chill settles in. A thermos of coffee sits nearby should I become drowsy. Also within easy reach is a powerful flashlight in case of unexpected guests . . . human or otherwise.

Once it's dark, I work with dim red lights. I wear glasses and use a magnifier to read the star charts. At the eyepiece, I sometimes cover my head with a dark towel. This is a guideline known to all deep-sky hounds who sniff out ridiculously faint challenge objects. Extraneous light slows the hunt and compromises the view.

That goes even for showpiece objects, such as the Swan (or Omega) Nebula (M17), which glides majestically near the Scutum-Sagittarius border. Shortly after dusk this night the celestial swan came to life for me, thanks to the heady combination of darkness, aperture, and filters.

Pollution filters may seem like overkill in the boonies but I find that they help in any conditions. I threaded a filter on the back of a wide-angle, 62x eyepiece and stole a peek.

The Swan floated right-side-up in a sea of stars. A dark patch at one end of its barlike body helped form a head and curving neck. Thanks to the high-contrast view, I detected a wispy extension curling off the other end — a leg dragging lazily in the water. Exceedingly faint striations immediately below the bird shimmered like moonlit ripples.

I switched to a 220x eyepiece and filter. This combination produced almost anatomical detail. Dark lanes cutting diagonally across the nebula gave the Swan a feathery texture. A wedge of material over its back suggested a raised wing. A star just above its head was wreathed in a tuft of hydrogen — a jeweled crown for a regal creature.

Such stunning sights remind me how much more appealing an isolated, high-elevation site is than a spot nearer to sea level — and civilization. For example, my home sits on a Cascade foothill on the south edge of the Fraser

IF YOU GO

Alpine observing is not for everyone. Getting there is always fun, but coming back when you're beat is less fun. Traveling to a remote site is expensive and time-consuming, more so if you decide to camp over (if your spot allows camping). And for all that effort, a lofty summit is often bone-chilling even in summer. The wind howls on the clearest nights . . . sometimes it makes the clearest nights. And sometimes it doesn't. Don't head for the hills after a cold front passes through unless you're sure the clouds have pushed clear of the mountains, too. It's a good idea to scan the latest satellite images and forecasts first.

Ken Hewitt-White

I often observe alone, so my van is equipped with a survival kit consisting of first-aid supplies, water, energy snacks, warm winter clothes, and a down sleeping bag. A cell phone would be a good idea, too, although they may not always work between the high mountain crests.

Last September I almost purchased a cell phone but, true to form, bought a high-end eyepiece instead. Heading home one night a few weeks later, my aging camper quit on me. I soon realized you can't dial up emergency road service on a new eyepiece. The sleeping bag came in handy, though. — *K. H-W.*

Starry details and additional rosy wisps appear around the Swan, or Omega, Nebula under ideal observing conditions. Jason Ware

Valley, halfway between Vancouver and the lookout. The sky from my yard is light polluted in the west but fairly dark in the east. Nebula filters come to the rescue on nights when I observe there, but even filters can't deliver the satisfyingly subtle detail I'm after, such as the Swan's "raised wing" and "crown." This is what propels me on the 90-minute drive to my mountain Mecca. The lookout's southern sweep and riveting black sky is irresistible. Its magnificent alpine setting is the icing on the cake.

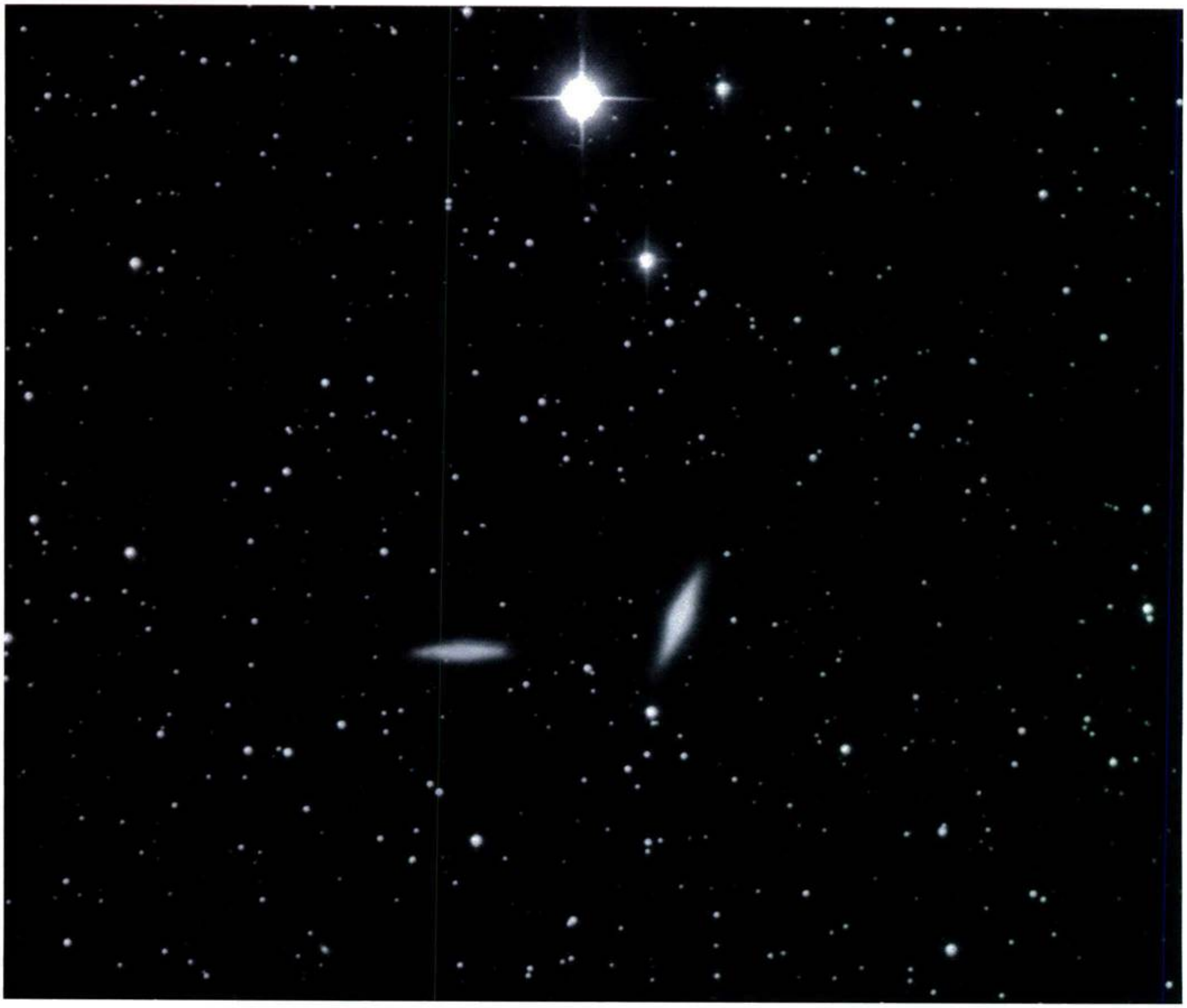
COSMOS OVER KOBAU

When I have a weekend or longer I pack my camping gear and drive an extra three hours eastward to Mount Kobau (pronounced COE-bo), which rises from the floor of the Okanagan Valley near the border of British Columbia and Washington. Mount Kobau was selected in 1964 as the site for a major Canadian observatory, but unfortunately the project succumbed to government spending cuts a few years later. Today, Kobau's broad, 6,200-foot summit is patronized by amateur astronomers in search of dark skies. In fact, this is the site of the annual Mt. Kobau Star Party (MKSP), now in its 17th year.

A reward awaits those who endure the 12 miles of rocky washboard to the summit. The arid Kobau ridges are scented with sagebrush and conifer and wrapped in a 360-degree panorama of sun-scorched peaks. At night, the view extends upward to a velvet vault studded with stars and strengthened by the long, glittering arch of the Milky Way. Every August I make my pilgrimage to Kobau to ingest this elixir of mountain air and celestial treasure. It utterly transforms me.

Some of that transformation takes place because I'm able to get some rest. I confess that my Cascade site is attractive to early risers in search of a sunrise photo-op and is therefore not well suited to someone who has pulled an all-nighter and is in need of some morning sleep. At Kobau, deep-sky diehards stake out their turf and camp.

A number of years ago during an MKSP, one of my Kobau friends introduced me to a pair of edge-on galaxies. His quarry lay a couple degrees west of Lambda Pegasi, not far from the asterism of the Great Square. Scanning the relevant chart, I wondered how I'd missed this gem. If you have black skies and clean optics, you'll find the galaxies worth a look, too.



The easily missed edge-on spiral galaxies NGC 7332 and NGC 7339 lie not far from the Great Square of Pegasus. Martin Germano

The twosome consists of 11.1-magnitude NGC 7332 and 12.2-magnitude NGC 7339. They are 5' apart on an east-west line and are oriented almost at right angles to each other. The smaller NGC 7339 (2.6' by 0.8') nearly intersects the larger NGC 7332 (3.7' by 1.0'). At low magnification in my 10-inch scope, the galaxies appear as delicate slivers flanked by two 7th-magnitude stars half a degree apart, aligned north-south. The northern star, only 12' north of the twin targets, nearly swamps the slender thread of NGC 7339, so slap on the power and keep that star out of the field.

Both objects make a nice composition in my 17-inch scope at a magnification of 400x. Like a classic edge-on galaxy, NGC 7332 sports tapered ends, an obvious core, and a starlike nucleus. On the other hand, NGC 7339 is a bit fuzzy with only a gradual brightening toward the middle. Its two ends are not sharply pointed. Yet NGC 7339 displays a subtle asymmetry. The side closest to its mate is brighter than the side facing away. When the sky is really steady, NGC 7339 has a mottled texture, and you may even be able to make out some dark knots.

In cases of high-power scrutiny, the seeing can be more important than the transparency. Wait for that perfect, rock-steady night, hunt down the Pegasus pair, and see for yourself.

DELICIOUS DETAILS

Rarefied mountain air turns my two telescopes into overachievers. I'm amazed at how often a challenging target in the 17.5-inch scope is also visible in the 10 incher, albeit dimly. I could cite all sorts of examples, but the most satisfying one involves a tiny object I lucked onto near the fine Draco planetary, NGC 6543, the Cat's Eye Nebula.

The story begins on an unseasonably cold, wind-swept night during the 1994 MKSP. Taking advantage of an idle 25-inch Dobsonian, I began examining the unique, aqua-colored doughnut that forms the Cat's Eye. A few minutes later, I nudged the scope slightly eastward to have a peek at neighboring NGC 6552, a nondescript 13th-magnitude galaxy. It was only upon returning to the Cat's Eye that my averted vision picked up a faint, round glow a little more than 1' west of the nebula. At the time, I assumed this was also a galaxy and thought no more of it.

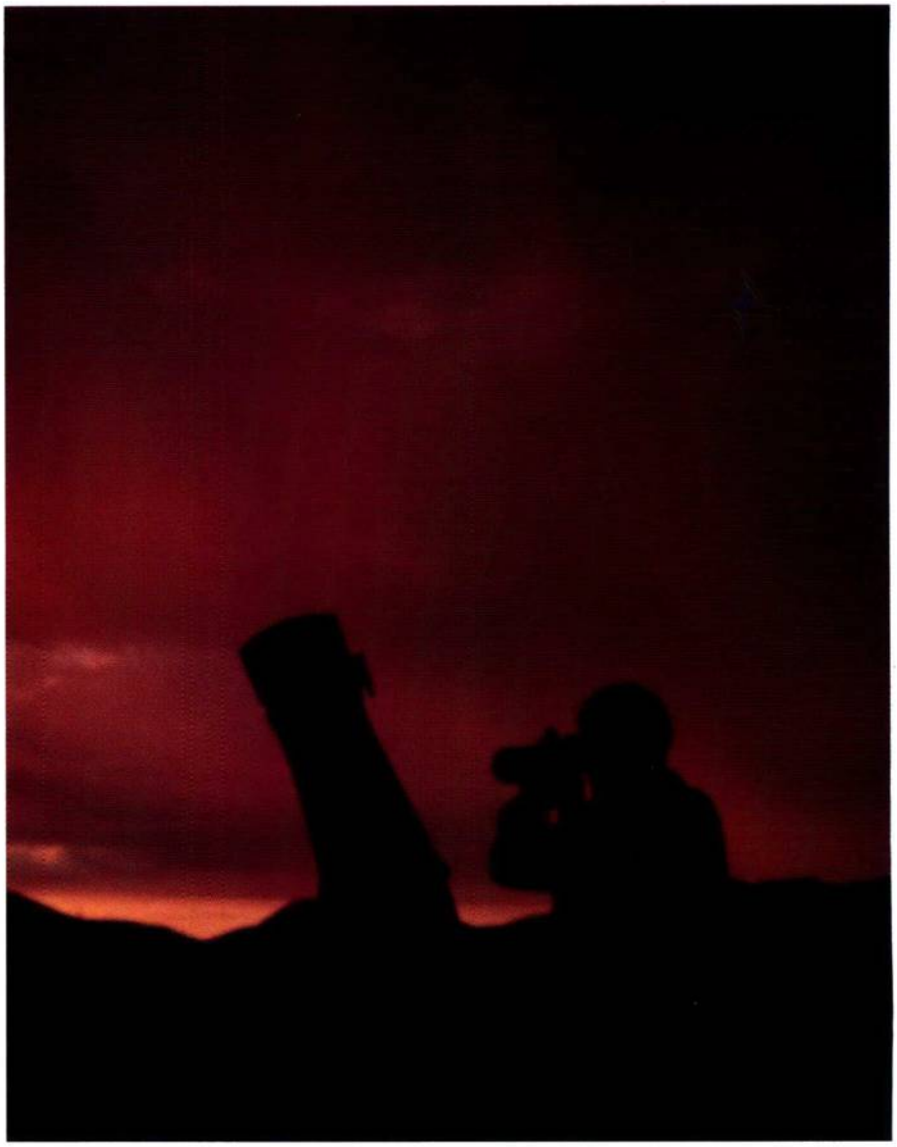
Fast-forward now to September 1999 at the Cascade Lookout. I was admiring NGC 6543 in my big Dob at 300x. It was no surprise to spot the nearby NGC 6552, but I was pleasantly shocked to detect the smaller blob as well. This time I gave it more of my attention. Using averted vision, I saw it on and off for several minutes. Excited now, I barked this information into my tape recorder, then returned to the planetary NGC 6543.

Because the Cat's Eye Nebula shines brightly in the light of ionized oxygen, I applied an OIII filter. This was a brute-force exercise to see how much detail I could pry out of that small, but tantalizing, smoke ring. Usually, I prefer the appearance of the Cat's Eye in natural light. Its 11th-magnitude central star remains distinct; the pastel hue of the surrounding shell stays true; and the vaporous feel of the extended halo is sublime. In fact, these are the kinds of delicious details that the mountain serves up time and again and are often missing at sea-level sites, even isolated ones.

On this occasion, the OIII helper paid an instant bonus that changed my appreciation of the Cat's Eye forever. With the filter in place, the tiny and mysterious blob shone steadily without averted vision. "A-ha," I thought, "it responds to oxygen just like the Cat's Eye." Later, I identified the smudge as IC 4677 and was amused to find that it's mislabeled in several catalogs as a galaxy. However, a little Internet sleuthing confirmed my suspicions that IC 4677 is now regarded by experienced observers as an outlying knot of the Cat's Eye. The 15th-magnitude filament can be found by dialing in the coordinates of the Cat's Eye Nebula: R.A. 17h58.3m, Dec. 66°38' (2000).

Occasionally the alpine is a harsh mistress. It was no fun the weekend the Kobau access road took out two of my tires, once going up and once coming down. I still shudder at the memory of a long-ago night high in the Rockies that was cut short by a real, live Ursa Major ambling by the telescope. And you can imagine the disappointment at last year's Kobau Star Party, when I — and nearly 200 other excited observers — stood by helplessly as a cold low front parked itself over the mountain for the entire week.

But my worst calamity occurred during that blustery 1994 MKSP. I was chairing the Saturday afternoon talks when a violent storm kicked up. Someone interrupted the proceedings to announce breathlessly that he had just witnessed my hefty Dobsonian achieve suborbital flight. Surveying the damage later I was relieved to see that while the plywood rocker had split apart and the box was fractured, the main mirror had endured an end-over-end tumble along the tube without a scratch. Patched and glued, the telescope returned to service a few nights later.



The isolation of high-altitude observing keeps out light pollution but can make getting there a challenge. Ken Hewitt-White

DRIVING PASSION

That Big Blue Beater still accompanies me on every observing run. While I was setting it up at the Cascade Lookout one evening a few years ago, an inquisitive tourist asked if the thing ran on batteries. "No," I replied, "it runs on muscle-power, duct tape, and passion." The muscle-power drops off after midnight, and I'm always running out of duct tape, but the passion never ends. It fuels my lasting interest in deep-sky wonders and my ceaseless desire to motor up mountains so I can get a closer look at the heavens.

I'd tell you more, but I hear that alpine siren calling again. It's the dark of the moon, a fresh westerly has scrubbed the sky clean, and the sun goes down in a few hours. See you on the mountain. A

Ken Hewitt-White was bitten by the deep-sky bug in 1967 and hasn't recovered since. He is the author of a new book for children, The Holographic Night Sky Book & Kit *(Somerville House).*

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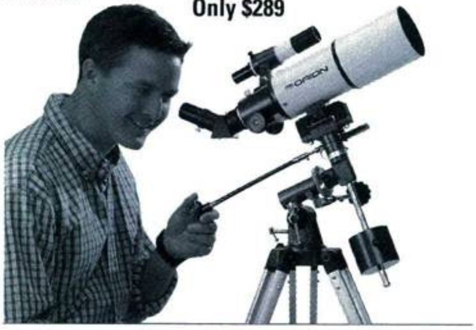

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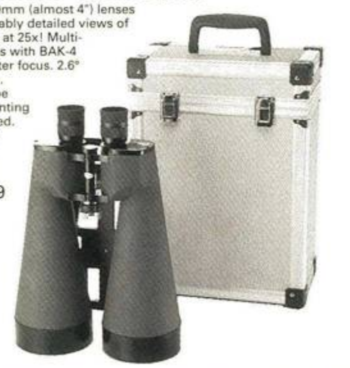

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Planets and moon take center stage.

by Martin Ratcliffe and Alister Ling

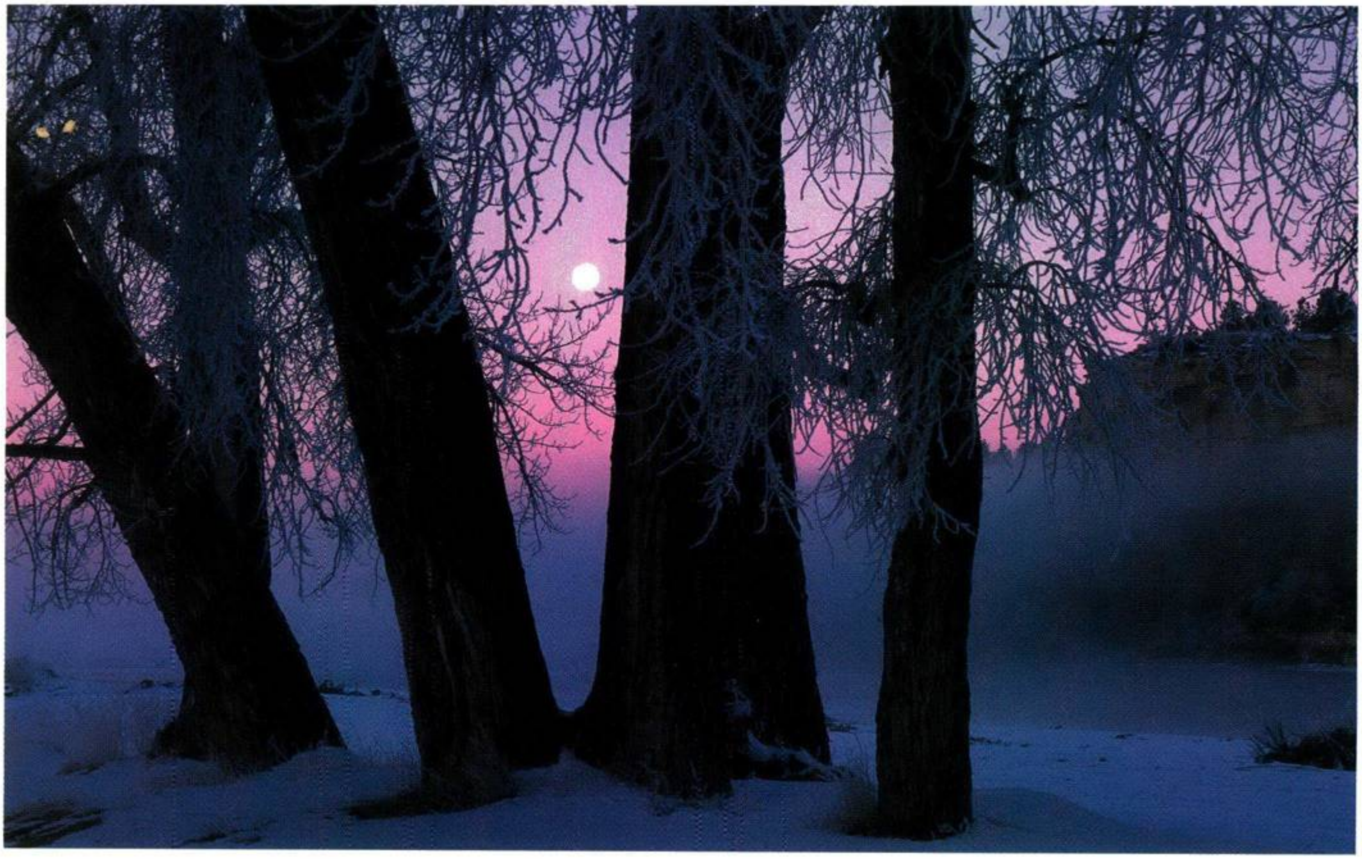
▶ If you're thinking of skipping current chilly observing sessions and waiting for the mild nights of summer, you'll be missing the best solar system action. Mars is the only planet that will grace summer skies, but now Earth's neighboring worlds are ready and waiting. Mercury displays a thinning crescent as it plunges out of sight in the first week of February, while the blazing Venus elegantly follows suit at a more graceful pace. Jupiter and Saturn command the sky high in the south, surrounded by their dancing moons.

As February begins, the thick crescent moon forms a line with Saturn and Jupiter in the evening sky. In two days the moon has slipped to the other side of the planetary pair. Full phase eludes both Jupiter and Saturn, which is evident by their soft twilight limbs. On the morning of the 15th, Mars, only 90-percent illuminated, can be found cowering below the moon, with the Red Planet battling its eternal opponent Antares to its lower left. Returning to the evening sky on the 26th, the crescent moon lies far left of Venus, itself a 23-percent crescent. By the last evening of February, the moon once again forms a line with Jupiter and Saturn.

Here's a simple, worthwhile project that takes only 10 minutes an evening. Follow the crescent phases of Mercury and Venus as they dwindle rapidly. Every couple days you will be able to notice a difference. The prominent line of Mercury, Venus, Saturn, and Jupiter charts the racetrack-like shape of their orbits. They appear in a line because we are inside the racetrack and see the solar system edge-on. Astronomers call this line the ecliptic. But the solar system is not perfectly flat, which is evident through naked-eye observation.

At the start of the month, Venus sits barely off the line that joins the sun to Saturn and Jupiter. By the end of February, Venus is clearly to the right, and it will continue to steer off northward as we head into March. Right now Venus just happens to be climbing toward its maximum height as it swings between us and the sun.

This frosty moon was photographed last winter on February 20, 2000. John McNeal



February
2001

1 First quarter moon is at 9:02 A.M. EST

2 The moon passes 2° south of Saturn, 5 A.M. EST
The moon passes 3° south of Jupiter, 5 P.M. EST

7 The moon is at perigee (221,738 miles from Earth), 5:17 P.M. EST

8 Full moon is at 2:12 A.M. EST

9 Uranus is in conjunction with the sun, 7 A.M. EST

12 Mercury is in inferior conjunction, 7 P.M. EST

14 Last quarter moon is at 10:23 P.M. EST

15 The moon passes 3° north of Mars, 5 A.M. EST

18 The moon passes 0.5° north of Ceres, 2 A.M. EST

20 The moon is at apogee (252,483 miles from Earth), 4:39 P.M. EST
The moon passes 2° south of Neptune, 6 P.M. EST

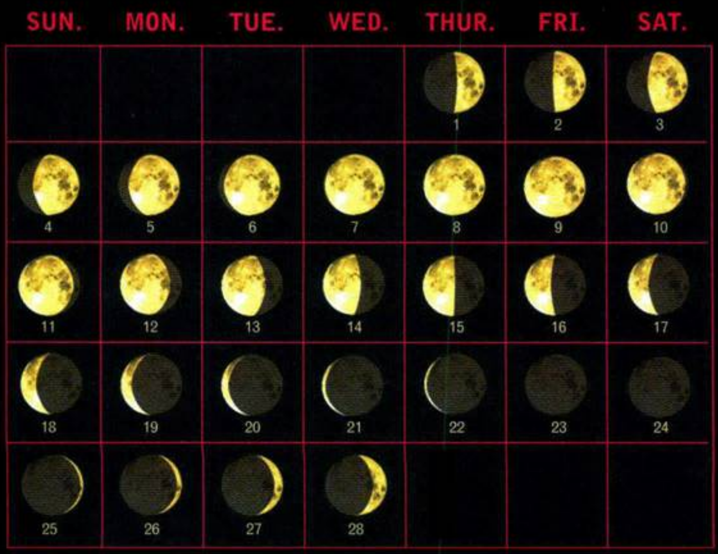
21 The moon passes 6° south of Mercury, 11 A.M. EST
Venus is at greatest brilliancy (magnitude –4.6), 8 P.M. EST (page 67)

23 New moon is at 3:21 A.M. EST

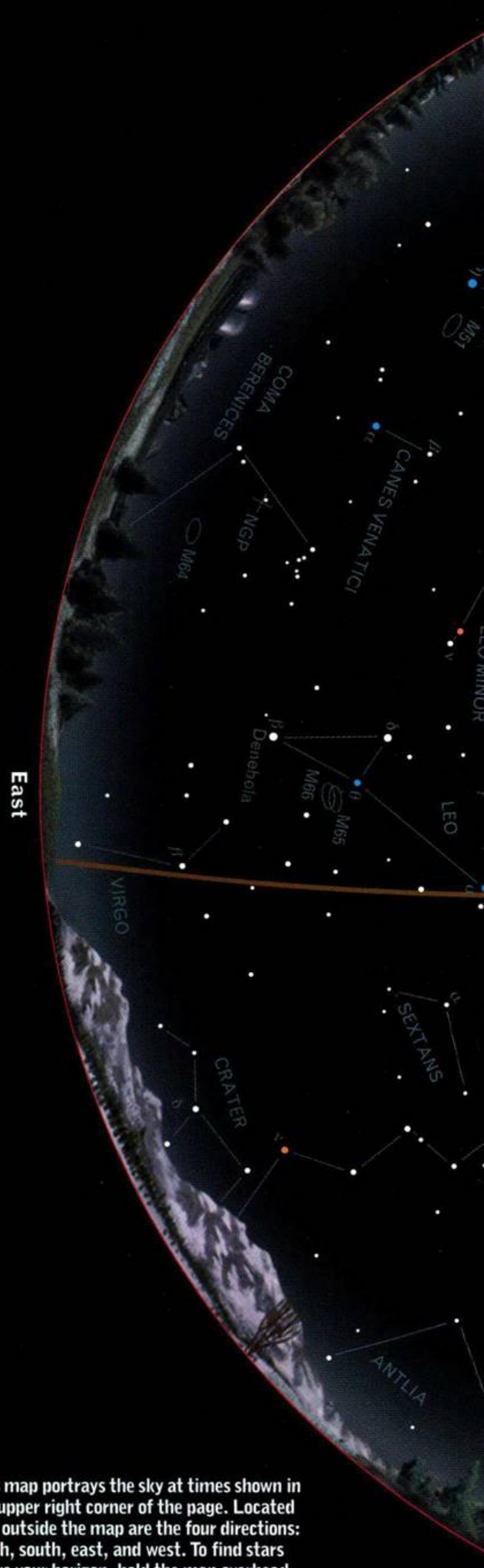
24 The moon passes 0.2° north of Vesta, 2 P.M. EST

25 The moon passes 1.0° south of Juno, noon EST

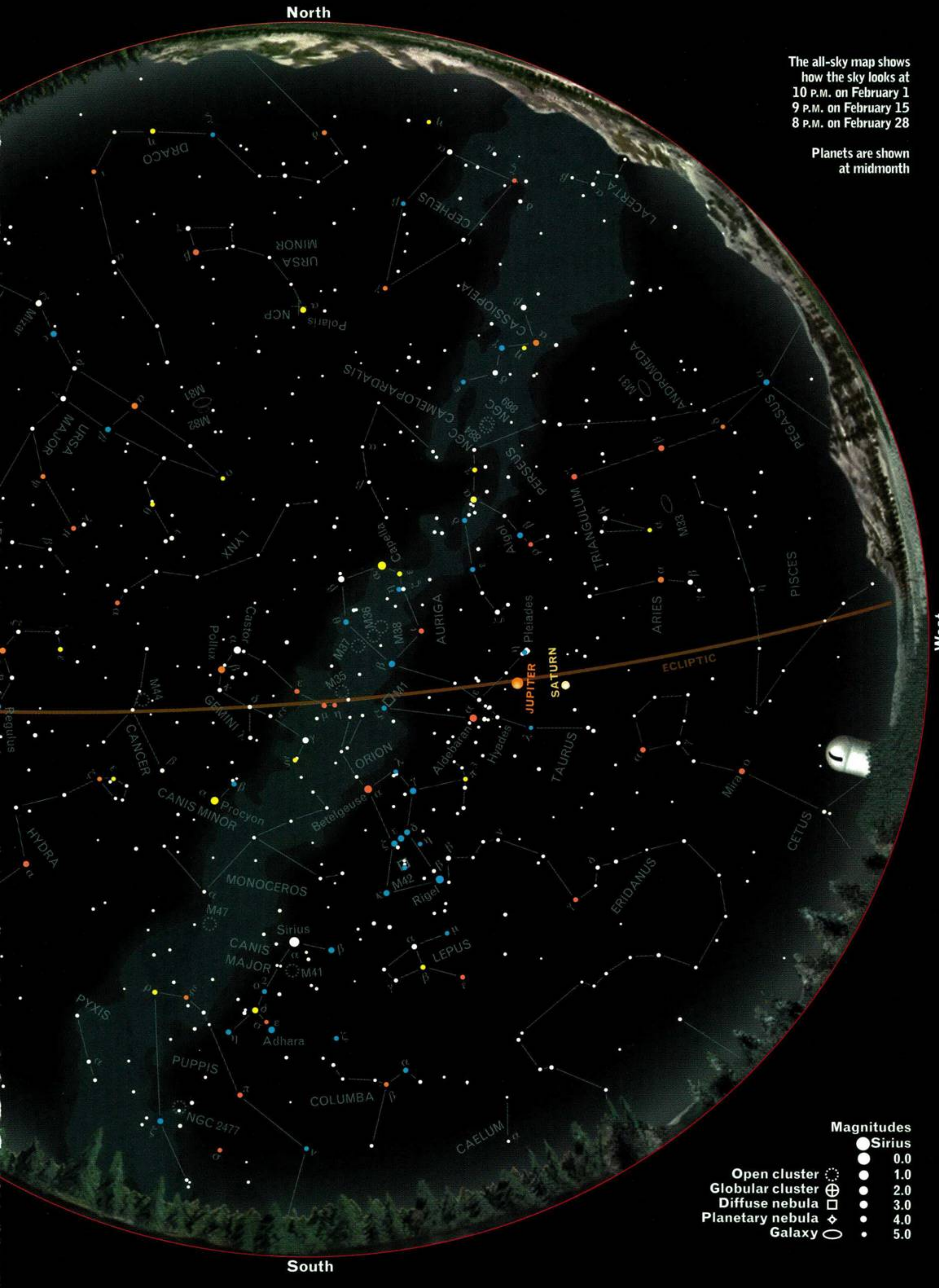
26 The moon passes 11° south of Venus, 3 A.M. EST



SUN.	MON.	TUE.	WED.	THUR.	FRI.	SAT.
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28			



This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

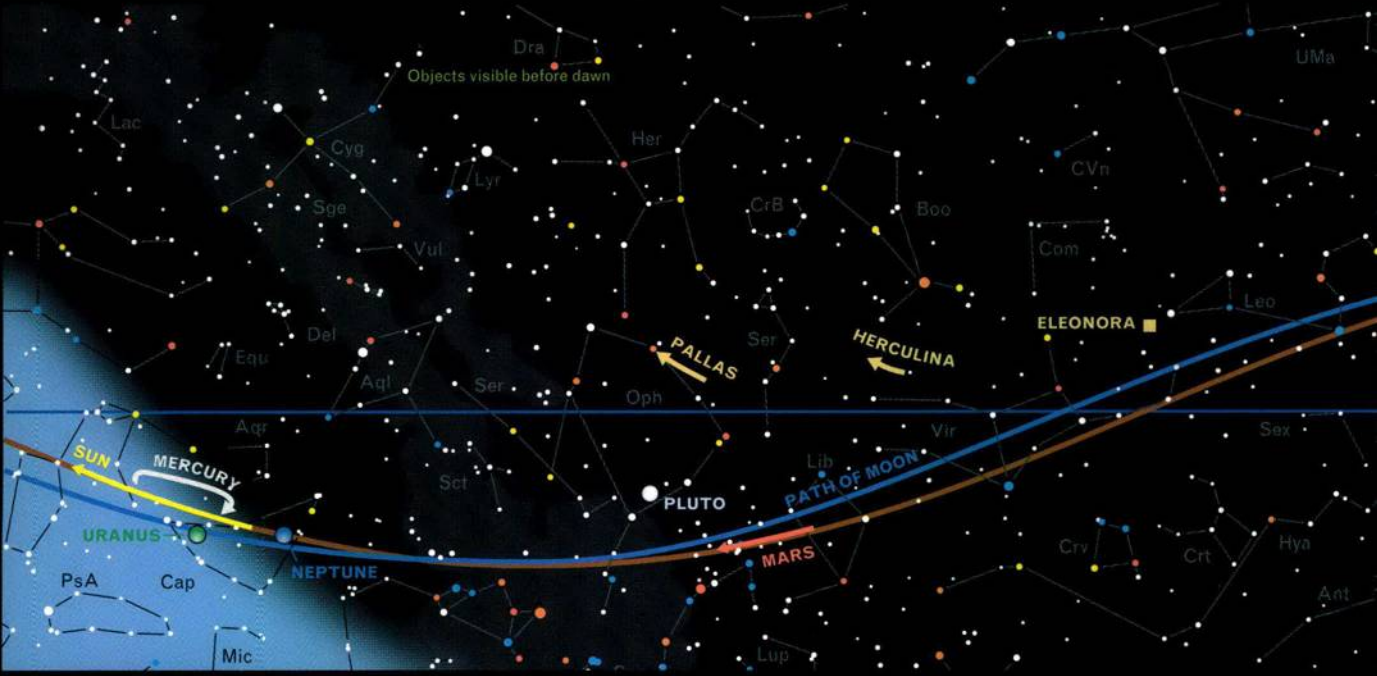

North
South
West
DRACO
CEPHEUS
LACERTA
URSA MINOR
NCP
Polaris
Mizar
CASSIOPEIA
ANDROMEDA
M31
CAMELOPARDALIS
M81
M82
URSA MAJOR
NGC 869
NGC 884
PERSEUS
PEGASUS
TRIANGULUM
M33
LYNX
Capella
Algol
AURIGA
M36
M37
M38
Castor
Pollux
Pleiades
ARIES
PISCES
M44
M35
M1
JUPITER
SATURN
ECLIPTIC
Regulus
GEMINI
CANCER
Aldebaran
Hyades
TAURUS
ORION
Mira
CETUS
CANIS MINOR
Procyon
Betelgeuse
HYDRA
MONOCEROS
M42
Rigel
ERIDANUS
M47
Sirius
CANIS MAJOR
M41
LEPUS
PYXIS
Adhara
PUPPIS
COLUMBA
NGC 2477
CAELUM
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows
how the sky looks at
10 P.M. on February 1
9 P.M. on February 15
8 P.M. on February 28

Planets are shown
at midmonth

Path of the Planets

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects


Dra
Objects visible before dawn
UMa
Lac
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PALLAS
HERCULINA
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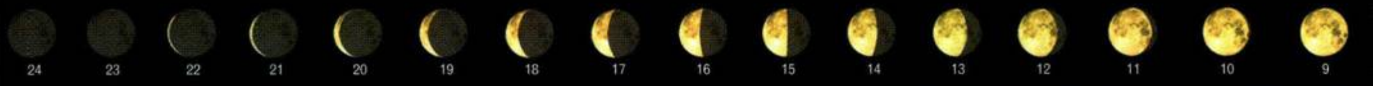
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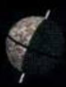
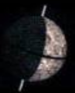
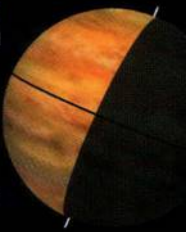
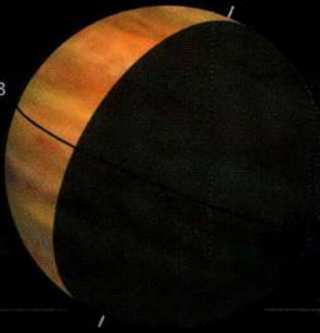
To locate the moon in the sky, draw a line from the phase s

PLANETS	MERCURY	MERCURY	VENUS	VENUS
Date	February 1	February 28	February 1	February 28
Magnitude	–0.1	0.7	–4.5	–4.6
Angular Size	7.8"	8.8"	28.9"	42.7"
Illumination	38%	33%	43%	22%
Distance (AU) from Earth	0.868	0.763	0.578	0.391
Distance (AU) from Sun	0.308	0.425	0.719	0.719
Right Ascension (2000.0)	22h06.2m	21h10.8m	23h51.9m	0h50.7m
Declination (2000.0)	–10°33'	–14°42'	0°42'	11°32'



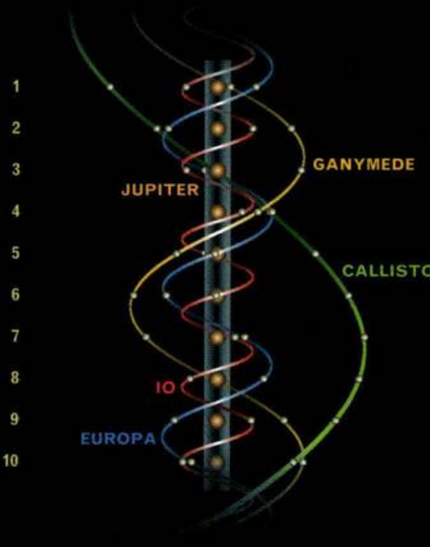






Jupiter's Moons

Dots display positions of Galilean satellites at 11 P.M. EST on date shown. South is at top to match the view in a telescope.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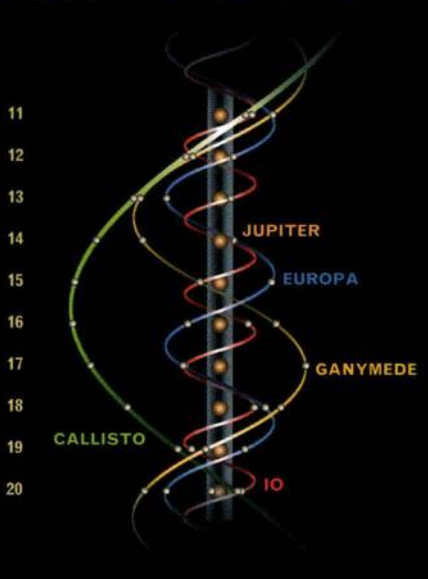
JUPITER
GANYMEDE
CALLISTO
IO
EUROPA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JUPITER
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GANYMEDE
CALLISTO
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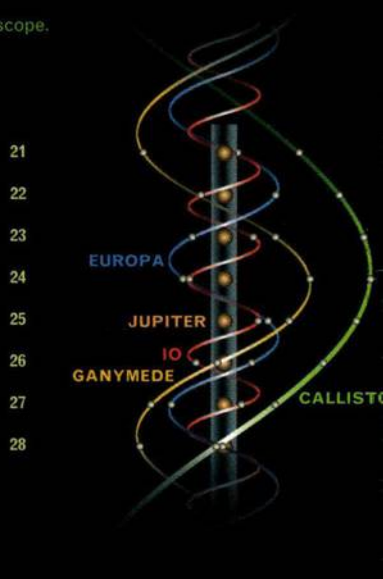
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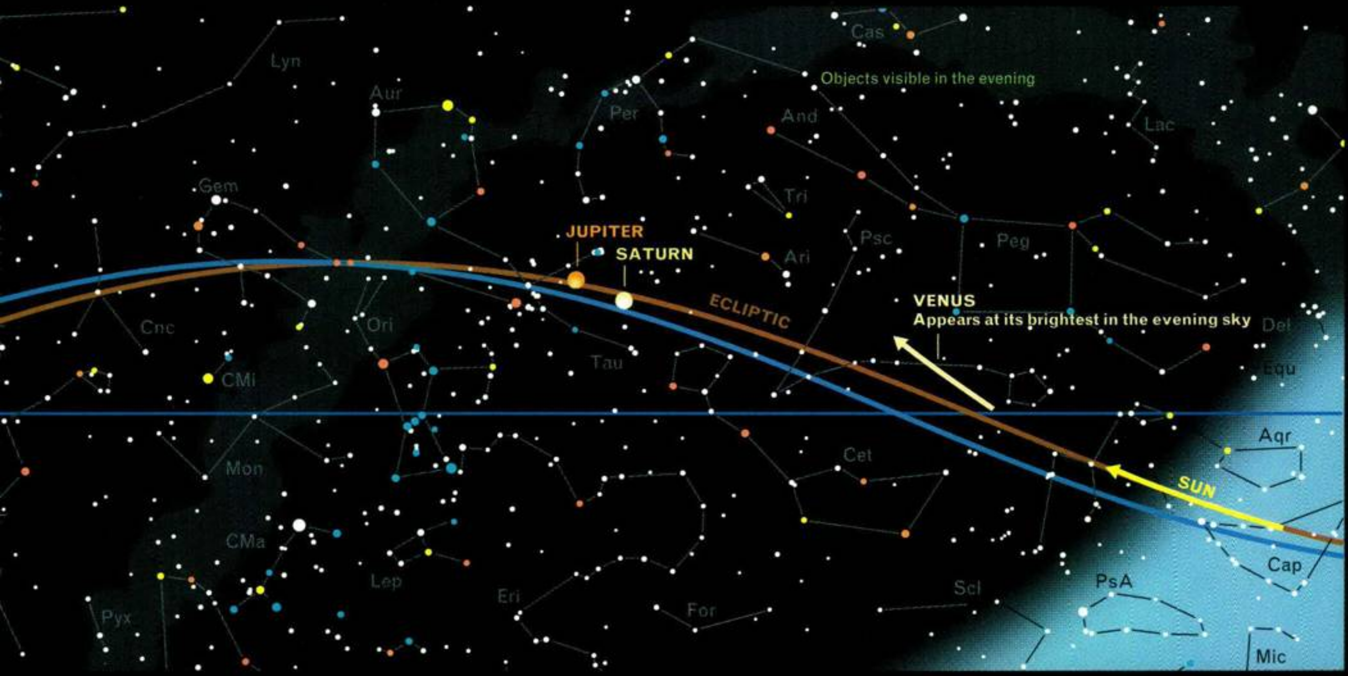
EUROPA
JUPITER
IO
GANYMEDE
CALLISTO

during the month.


Lyn
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Objects visible in the evening
And
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ECLIPTIC
VENUS
Appears at its brightest in the evening sky
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Cet
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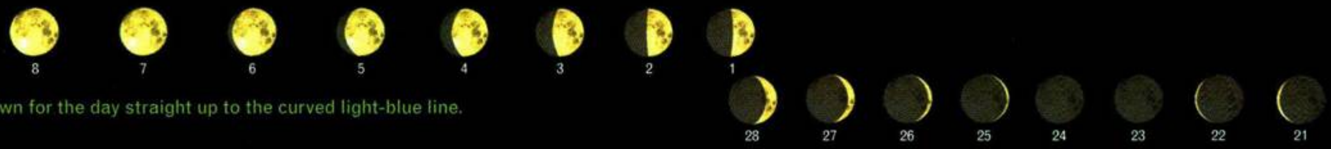
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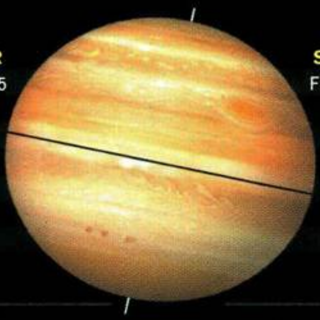
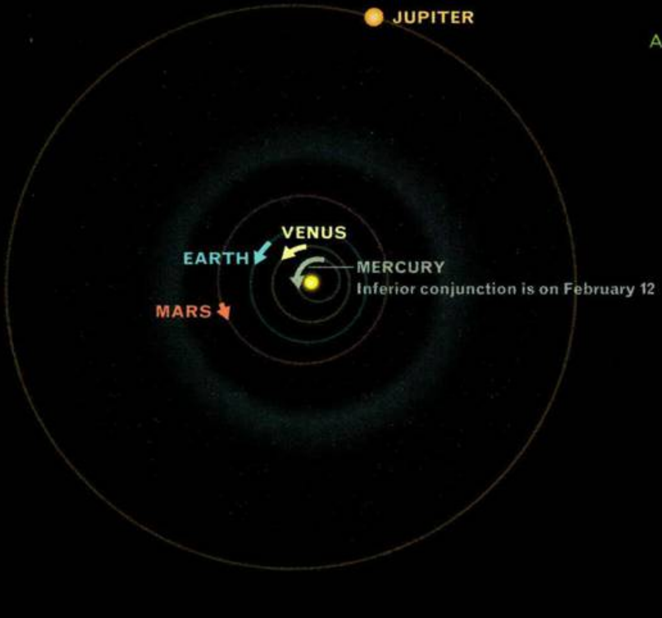
own for the day straight up to the curved light-blue line.



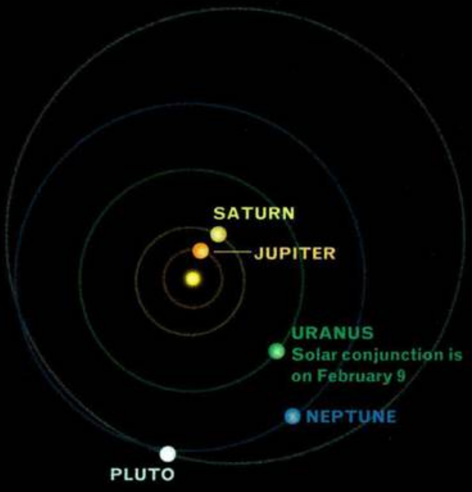
MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
February 15	February 15	February 15	February 15	February 15	February 15
0.8	−2.4	0.1	5.9	8.0	13.8
7.0"	40.5"	18.3"	3.4"	2.2"	0.1"
90%	99%	100%	100%	100%	100%
1.343	4.868	9.085	20.945	31.036	30.648
1.614	5.060	9.106	19.962	30.106	30.352
15h52.5m	3h59.7m	3h30.4m	21h35.0m	20h37.4m	16h59.6m
−19°10'	19°56'	16°57'	−15°06'	−18°22'	−12°13'

The Planets in Their Orbits

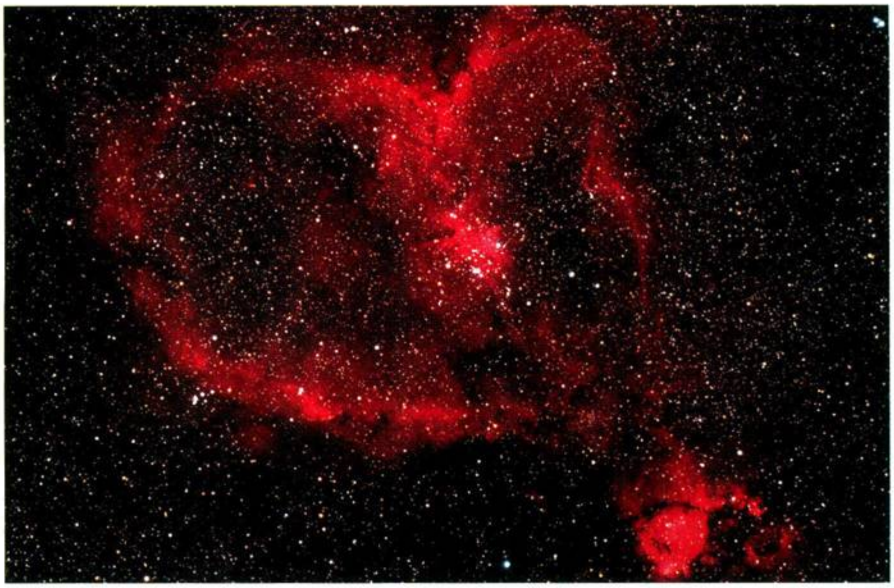
Arrows and dots show planets' positions during the month.


JUPITER
VENUS
EARTH
MERCURY
MARS

Inferior conjunction is on February 12


SATURN
JUPITER
URANUS
NEPTUNE
PLUTO

Solar conjunction is on February 9



IC 1805 forms a heart shape and is appropriate viewing for February. Tony and Daphne Hallas

Renowned for a myriad of star clusters that cover her from head to toe, Queen Cassiopeia has hidden her true heart away from the throngs that seek her. Like a box of Valentine's chocolates, the glowing red wreath of Cassiopeia's best gas cloud contains several delights for you to sample.

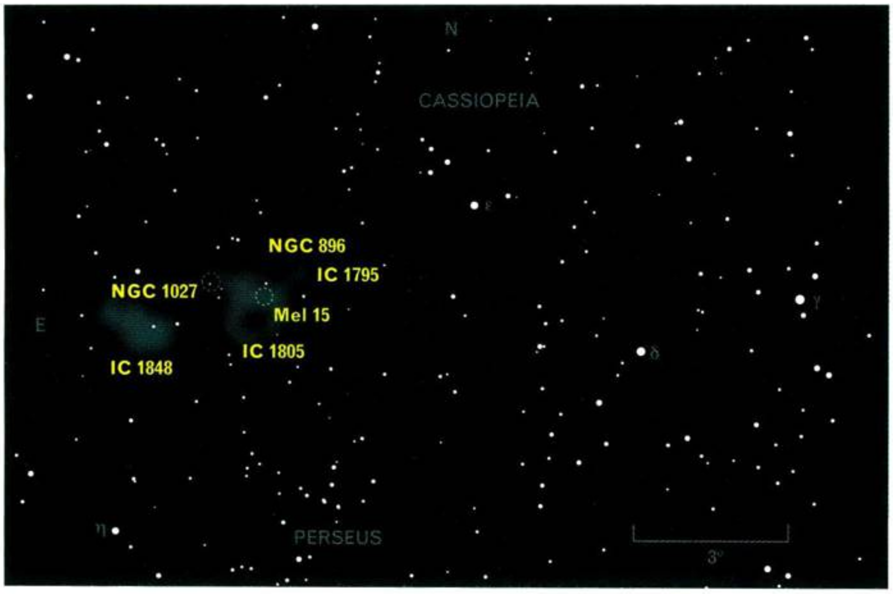
Every spiral arm of the Milky Way Galaxy marks the birthplace of glittering stars, compressing dust and gas into cocoons that populate a giant nursery. Although the Perseus arm is situated away from the center of the galaxy, plenty of gas and dust still inhabits the area to forge a heart for Cassiopeia.

One of the heart's delights can be seen from the backyard in a 4-inch scope — the bright star cluster Melotte 15. It was too large and scattered for the eagle eye of master observer William Herschel to detect more than 200 years ago. A handful of brighter stars appears to radiate outward over an elliptical background of gradually fainter stars, spanning two-thirds of a moonwidth in a low-power eyepiece.

To find Melotte 15, start at the middle star of Cassiopeia's "W," head toward Perseus by splitting the distance between the next two stars of the "W" and traveling that distance before stopping on the other side. A pair of 7x50 binoculars or a finderscope should reveal the small clump. A bit more than 1°, or two moonwidths, farther east, which is to the right when Cassiopeia is in her current upside-down position, you can see another star cluster from an urban backyard — NGC 1027.

Herschel found NGC 1027 to be a considerably scattered group of stars surrounding the brightest star, a 7th-magnitude gem. Two spiral arms of stars appear to wind outward from the brightest part of the cluster.

Both NGC 1027 and Melotte 15 are readily visible in binoculars under dark country skies. And without any special filters through a telescope, it is possible to just glimpse some of the faint nebulosity when your eyes are dark adapted.



In the darkness, the smallest of wide-field telescopes centered on Mel 15 will reveal Cassiopeia's translucent heart. Known as IC 1805, it was discovered by the famed American observer Edward E. Barnard. Your best view will be at the beginning or end of the month, when the moon is absent. A nebula filter will help enhance the ghostly glow.

The outline of the cardioid is most easily traced with a 10- to 20-inch scope. Some patience will also allow you to divine the distinctive V-shape on its eastern flank. As you swing to the west, just when you think the nebula ends, in pops the double gas cloud NGC 896 and IC 1795. Nebula filters help increase the contrast of these two amorphous blobs against the background sky. Photos show some detailed structure here that you may see if you spend extra time viewing.

Every heart-shaped chocolate box comes with a lid. Only half a binocular field farther east lies IC 1848, a large oval glow of stars and cocooning gas. In dark skies this is a modestly prominent object through binoculars.

sky Show

Five Naked-Eye Planets Rule the Night

The February night sky is the best time this year for viewing planets. The three most brilliant adorn the evening sky. In addition, all five of the naked-eye planets that were known to the ancients are on view during the period between sunset and just after midnight.

Begin by looking west where Venus is obvious after sunset. Mercury makes an early month appearance nearby but is much more difficult to see. As the sky darkens after sunset, Jupiter and Saturn put on a show high in the sky to the south. Finally, Mars, the Red Planet, rises after midnight in the constellation Libra the Scales. The moon joins the fray as February opens, with a first-quarter moon standing 5° west of Saturn in Taurus the Bull.

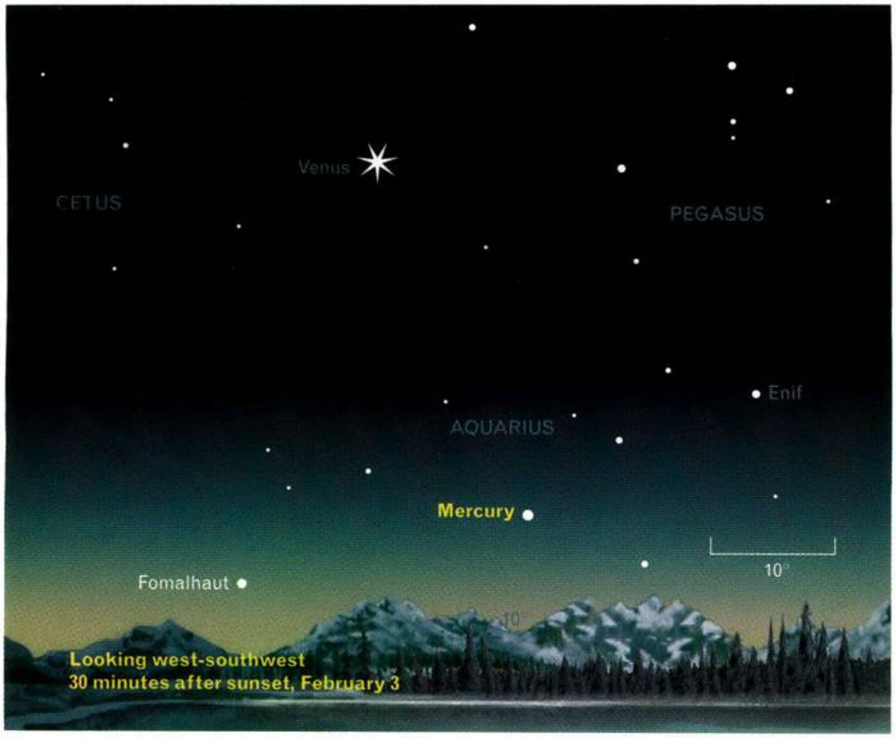
Mercury, one of the two inner planets of the solar system, continues its brief period of visibility that began in January. It remains west-southwest above the horizon for just over an hour after sunset on February 1 but sinks into the sun's glow by the end of the first week of the month.

Don't confuse Mercury with Fomalhaut, the bright star in Piscis Austrinus setting just to its south. Both objects have a similar brilliance. Mercury shines at magnitude 0.4 by February 3 and fades fast. A telescopic view shows why. As Mercury passes between the sun and Earth, its illuminated phase shrinks from 30 percent on February 1 to less than 20 percent by February 4.

The second inner planet, **Venus**, is much easier to see than Mercury for two reasons. It orbits farther from the sun at an average distance of 67 million miles, which consequently carries it farther away from the sun as seen from Earth and places it in a darker sky. Venus is also a larger planet, a twin of Earth in size and density, and has a highly reflective atmosphere, making it quite bright in our night sky. This month it reaches its greatest brilliancy at magnitude –4.6 in Pisces the Fish.

Venus's visibility undergoes great change this month, however, as it begins its slip into the sun's twilight glow. As it does so, it slides along Pisces from the circlet asterism toward Epsilon (ε) Piscium. Through any scope, Venus displays phases similar to the moon. Currently it has the appearance of a crescent, starting the month 42-percent illuminated and shrinking to 22 percent by February 28. At the same time its apparent diameter grows from 29" to a comparatively giant 43".

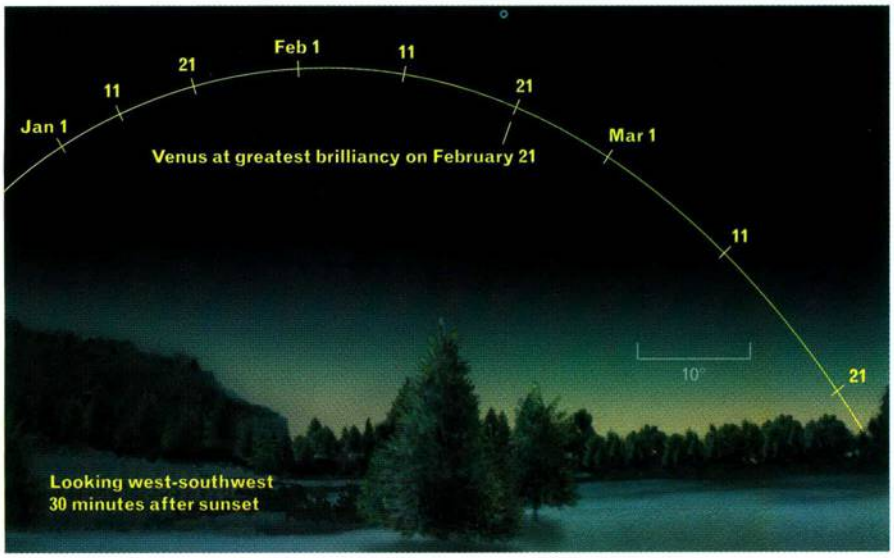
Jupiter and Saturn have been keeping company with the Pleiades and Hyades. Ivan Dryer



Looking west-southwest
30 minutes after sunset, February 3

As Venus sinks in the west, two brilliant planets dominate an already star-studded winter sky. Joining the bright stars of Orion the Hunter, Gemini the Twins, and Canis Major the Great Dog are **Jupiter** and **Saturn**. The pair meanders across Taurus the Bull between its brightest star, Aldebaran, and the splendid star cluster, the Pleiades (Seven Sisters, or M45). Keep in mind that Saturn is almost double the distance of Jupiter from Earth. The time for light to travel from Jupiter to Earth is currently 40 minutes, compared to Saturn's 75 minutes. This places them at 446 million miles and 837 million miles from Earth, respectively. Therefore you are viewing Saturn as it was 75 minutes ago, and Jupiter as it was only 40 minutes ago.

In early February, Jupiter shines at magnitude –2.5 and fades by two-tenths of a magnitude four weeks later. Its giant disk, spanning 42", makes atmospheric features easy targets for observers. Look for the Great Red Spot during the evenings. Any telescope should reveal it. It races around Jupiter



carried by the planet's rapid rotation rate of a few minutes shy of 10 hours.

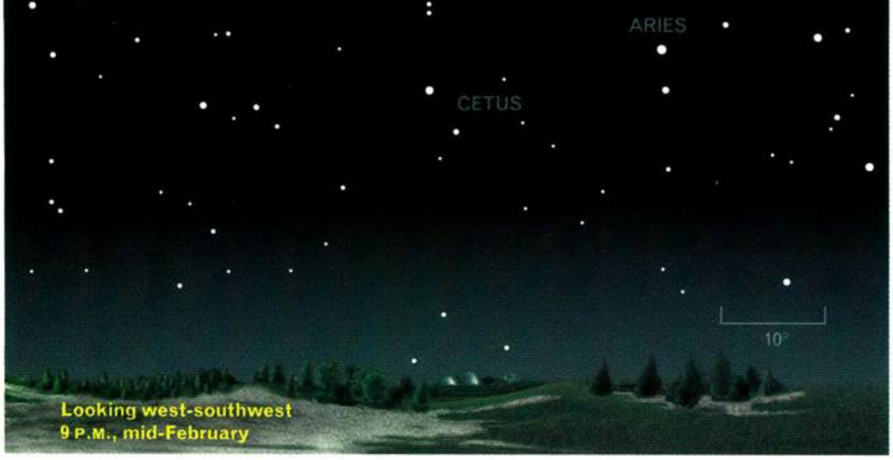
Jupiter is not a solid body, but rather a gaseous mass that has a differential rotation rate. Two standard rotation times are used as a comparison. The region between the equatorial belts is called System I and rotates in 9 hours and 50 minutes. The rest of the planet adopts a rotation rate of about 9 hours and 55 minutes. The Great Red Spot lies in the System II region. It lies on the southern edge of the South Equatorial Belt and can be followed over a few evenings. The spot should be visible most of the evening of February 2 and February 5, for example. During the intervening days it may be caught early or late in the evening.

Jupiter's rapid rotation brings various features into view each night, and tracking them can offer many satisfactory hours at the telescope. Many people take a quick look at the planet, but take your time and watch carefully. Patiently viewing the planet allows moments of steady seeing. These fleeting moments provide unprecedented detail on the planet's surface. You will soon become familiar with its many features. Jupiter also has four large moons that perform each night, and we'll take a closer look at those in the Meteors and Moons section (page 68).

Saturn is simply marvelous to view. Its remarkable rings captivate people, and the planet is an icon for astronomy. Any telescope will show off the rings, and most 60mm refractors, perhaps prevalent after the Christmas season, will reveal the Cassini Division, the most prominent of the gaps in the ring system. Observers will be hard pressed to see anything of significance in the atmosphere of Saturn. However, large white spots — giant storm systems — have occurred in the past and can occur again at any time.

Saturn shines at magnitude 1.0, and its yellowish glow contrasts nicely with the orange-red star Aldebaran. Its rings tilt by 23° to our line of sight, offering a fine view of its South Pole.

Rising after midnight among the stars of Libra is **Mars**. Glowing at magnitude 1.0, the fourth planet from the sun currently seems to outpace Earth on the orbital track. We will win the race by June, but until then Mars will remain in the morning sky for a while. As the distance between Mars and Earth shrinks, its brightness continues to grow, reaching magnitude 0.5 by February 28. By this time Mars has moved into Scorpius. The one-way travel time of light also drops to 10 minutes, placing Mars 111.6 million miles from Earth. This distance will shrink to 42 million miles by the time it reaches opposition in June of this year. Currently the disk of Mars spans a tiny 8", making it tough for anything except the largest telescopes to see much detail on the Red Planet. The story will change in two months, however, as we enter a springtime Mars observing season that will run through late summer.



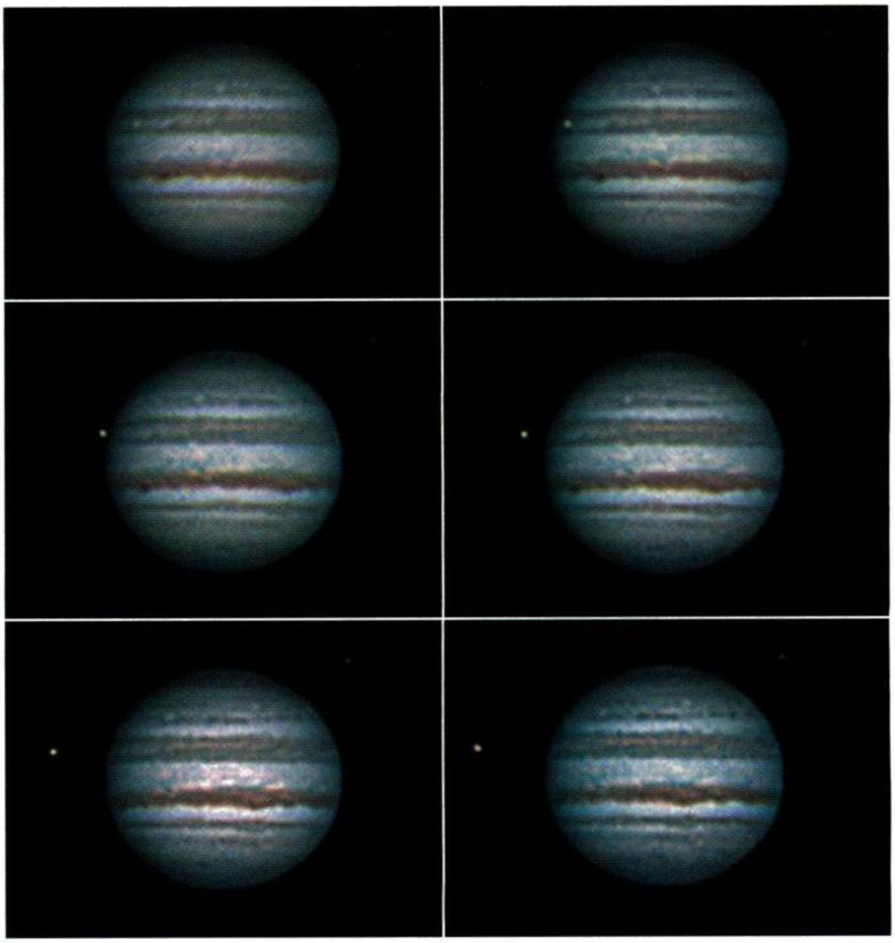
Solar System Satellites

The moons of both Jupiter and Saturn perform nightly orbital rituals that are fascinating to watch. Let's take a closer look at each set of moons in turn, starting with Jupiter and its four main satellites.

Jupiter's Moons

The four bright Galilean moons pass back and forth on either side of the giant planet as they orbit. Io, Europa, Ganymede, and Callisto undergo frequent eclipses, transits, and occultations that are within reach of small telescopes. Their changing relative positions occasionally present some interesting patterns. On February 4, for example, all four moons congregate on one side of the planet, creating a diamond formation. Watch for a few minutes and their positions will transform noticeably, particularly Io, which is the fastest moving. On February 11 the four moons congregate on the western side of the planet, this time as two pairs. Io and Europa lie close together, as do Ganymede and Callisto. Within a 10-minute period their relative positions will change.

Listed below are a number of events that occur in the early evening, with times accurate to 2 minutes. Make sure you take time to set up your scope at least 30 minutes before the start times so that you don't miss any event. Each moon is indicated by a Roman numeral as follows: Io = I, Europa = II, Ganymede = III, and Callisto = IV. Events are abbreviated as such: Tra = transit; Occ = occultation; Sha = shadow transit; Ecl = eclipse. Times are Universal Time; subtract 5 hours for EST, subtract 6 hours for CST, subtract 7 hours for MST, and subtract 8 hours for PST. Note that on all occasions the events occur on the previous date when subtracting these hours, so the February 2 event at 1:41 UT occurs at 8:41 P.M. EST on February 1.



A couple hours at the telescope reveal the dance of the Galilean moons around the largest planet, Jupiter. David Hanon

Tracking Galilean Moon Movements

III:	Occ end:	2 Feb. 2001	1:41
III:	Ecl start:	2 Feb. 2001	4:36
II:	Tra start:	6 Feb. 2001	1:06
II:	Sha start:	6 Feb. 2001	3:39
II:	Tra end:	6 Feb. 2001	3:43
I:	Tra start:	7 Feb. 2001	4:06
II:	Ecl end:	8 Feb. 2001	0:38
I:	Occ start:	8 Feb. 2001	1:25
I:	Ecl end:	8 Feb. 2001	4:53
I:	Tra end:	9 Feb. 2001	0:45
I:	Sha end:	9 Feb. 2001	2:04
III:	Occ start:	9 Feb. 2001	3:19
III:	Sha end:	13 Feb. 2001	0:55
II:	Tra start:	13 Feb. 2001	3:38
II:	Occ end:	15 Feb. 2001	0:34
II:	Ecl start:	15 Feb. 2001	0:37
II:	Ecl end:	15 Feb. 2001	3:17
I:	Occ start:	15 Feb. 2001	3:19
I:	Tra start:	16 Feb. 2001	0:29
I:	Sha start:	16 Feb. 2001	1:49
I:	Tra end:	16 Feb. 2001	2:40
I:	Sha end:	16 Feb. 2001	4:00
I:	Ecl end:	17 Feb. 2001	1:17
III:	Sha start:	20 Feb. 2001	2:41
III:	Sha end:	20 Feb. 2001	4:56
II:	Occ start:	22 Feb. 2001	0:33
II:	Occ end:	22 Feb. 2001	3:12
II:	Ecl start:	22 Feb. 2001	3:16
I:	Tra start:	23 Feb. 2001	2:24
I:	Sha start:	23 Feb. 2001	3:44
I:	Tra end:	23 Feb. 2001	4:35
II:	Sha end:	24 Feb. 2001	0:46
I:	Ecl end:	24 Feb. 2001	3:13
III:	Tra start:	27 Feb. 2001	1:19
III:	Tra end:	27 Feb. 2001	3:38

(Times are in Universal Time)

Saturn's Moons

Titan is the brightest of Saturn's moons, shining at magnitude 8.4. Any telescope of 4 inches in aperture will show it and also Rhea, Dione, and on good nights, Tethys. An 8-inch telescope will show Iapetus. A 10-inch telescope is required to spot Enceladus.

Titan lies due east of Saturn on February 2 and due west on February 10. Iapetus is harder to spot, because it also varies in magnitude. Iapetus appears brighter at its western elongation, and such an event occurs this month. Watch carefully as Iapetus moves from north of Saturn to its western side near February 18, when it should be noticeable in a 6-inch scope.

A recent discovery now claims 22 moons for Saturn, more than any other planet in the solar system. The four new companions, between 6 and 30 miles across, are too small to be seen in amateur telescopes. The satellites lie far from their home planet and have irregular orbits.

No Herculean Effort

Thanks to the elliptical orbits of asteroids, we frequently get the chance to view an otherwise tough observing target of the rocky solar system. The distance between us and the object is the key — if it ventures twice as close it becomes four times brighter. And our target is closer to the sun, which brightens it up even more.

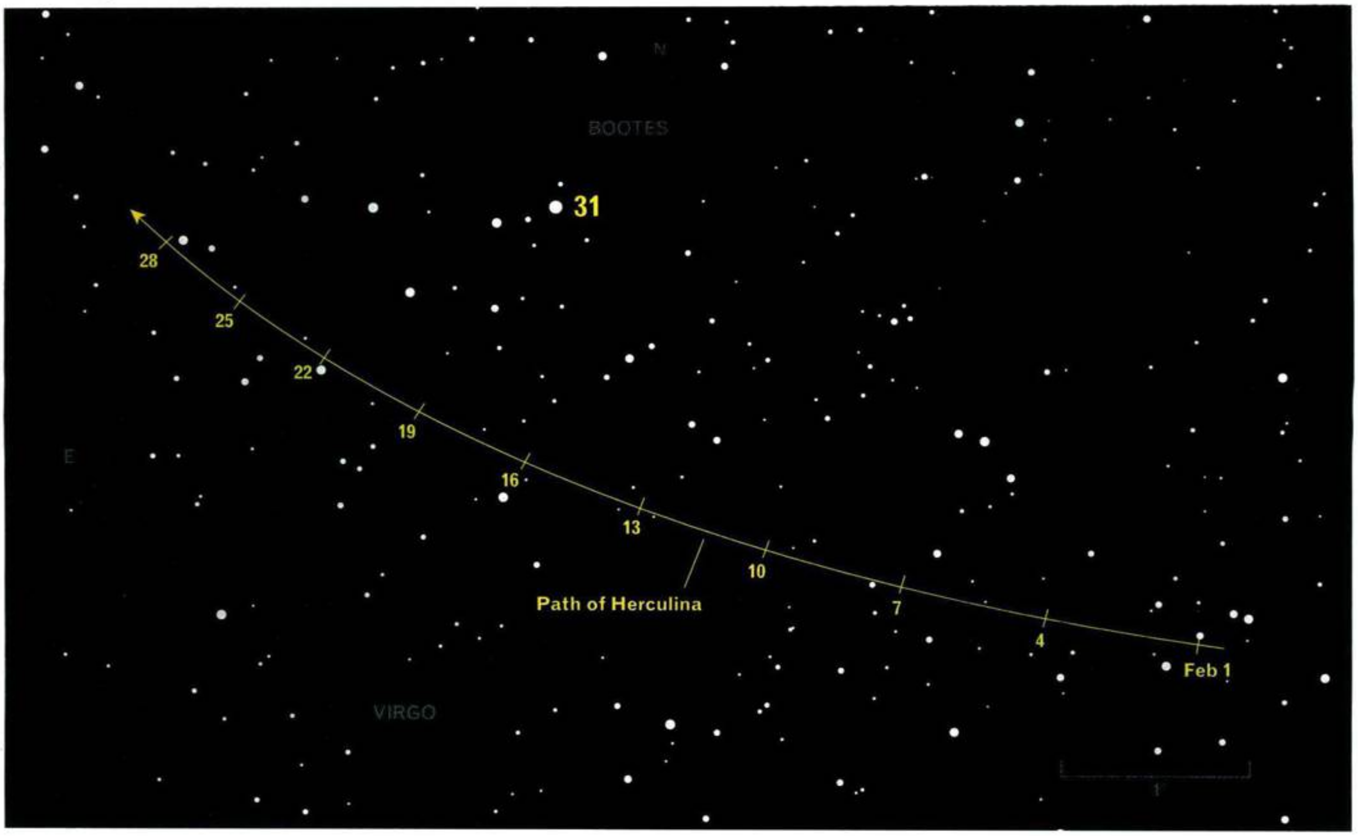
Despite being the 532nd asteroid to be discovered, Herculina is the 4th brightest asteroid visible this month, rising past 10th magnitude. Only three first-class asteroids outshine it: Ceres, Pallas, and Vesta. You don't have to leave your backyard to find Herculina because it will be readily visible in a small scope through an urban glow.

Start at Arcturus low in the northeast. If you live in the south, you'll have to wait until midnight before it rises. On the way to Herculina, stop off at Pi (π) Boötis — a whitish double star of 5th and 6th magnitude, separated by 5" (use over 100x) — and jump southward to the next star, which is Zeta (ζ) Boötis. If you've got at least an 8-inch scope, crank it past 300x on a steady night to see if you can split the 4.5-magnitude twins only 0.8" apart. This will be a real challenge with the star so low in the sky. Keep heading south to land on 31 Boötis, your anchor star.

Use the pattern of brighter 7th-magnitude stars on the chart to zero in on Herculina's nightly location. Because a number of field stars are of similar brightness, make a quick sketch of the area and come back another night to see which "star" moved.

Discovered on April 20, 1904, by Max Wolf in Heidelberg, 532 Herculina is now known to be 140 miles (230 km) across. Take the opportunity to easily track down this asteroid. ■

Martin Ratcliffe is Director of Theaters at the Exploration Place in Wichita, Kansas. Alister Ling is a meteorologist working for Environment Canada in Alberta.



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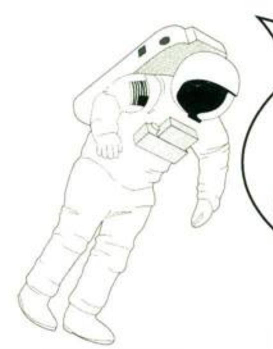

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By Philip S. Harrington Here is the perfect reference for anyone, who owns a telescope or a pair of binoculars but doesn't know what to look for amid the constellations. It explains how to find double and multiple stars, variable stars, open and gobular clusters, nebulae, and galaxies — what you'll see when you do Includes 36 full-page sky charts; equipment, books, and software suggestions; sketches of how deep-sky objects look through a small telescope; and more than 100 black & white photographs. 272 pages.

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TELESCOPES FOR THE MASSES

Versatile and affordable, Meade's ETX-60AT and ETX-70AT refractors are automated guides to the night sky.

by David J. Eicher

DON'T DISMISS THE POWER OF MEADE'S NEW ETX REFRACTORS SIMPLY because they're small, short-focus instruments. The ETX-60AT and ETX-70AT scopes, introduced this summer by the California telescope manufacturer, are computerized observatories designed to bring astronomy to the masses. They are "plug-and-play" units that require only a few minutes to unbox, set up, and prepare for observing. The procedures involved in setup, alignment, and target acquisition are so thoroughly automated that a bright child could accomplish the whole task. And the telescopes are priced affordably enough (list prices of $299 and $349, respectively: "street prices" from dealers may be cheaper yet) that Meade hopes to broaden the hobby of astronomy in part through the popularity of these ETX models. Based on *Astronomy*'s testing, they should have every reason to succeed.

Meade's **ETX-60AT** (inset) and **ETX-70AT** refractors bring "go-to" technology to the beginner's telescope market. The computer-linked keypad and database of more than 1,400 objects allow users to dial-in objects and command the scope to find them.

MULTI-COATED OPTICS
f/5.0
MEADE ETX-70 TELESCOPE
MEADE
COMPUTER CONTROL
ENTER
MODE
GO TO
MEADE
AUTOSTAR

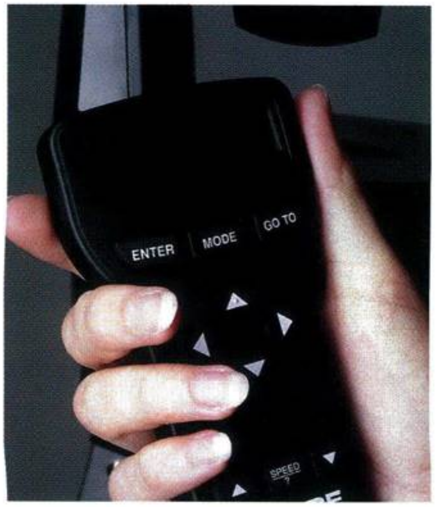
The core of the ETX refractor idea is a computerized database that requires simple inputs from a keypad to recall its location, date, and time before it offers up a wealth of data including the locations of 1,471 objects including planets, asteroids, comets, stars, galaxies, clusters, and nebulae. This digital brainpower allows the telescopes to function as alt-azimuth units that can locate objects at the touch of a button and then track them effectively — after orientation with several defining stars — without an equatorial mount or polar alignment. The whole point of the telescopes is to deliver a simple design that works straight from the box and offers many targets to look at with minimal effort. To keep the cost low, complexity is limited to the computer system; the lenses are simple achromats (2.4 and 2.8 inches in aperture, respectively), and plain, effective 25mm and 9mm modified achromatic eyepieces are supplied. Other than the difference in aperture, the elements of the ETX-60AT and ETX-70AT are identical.

In decades past, the astronomy world has bemoaned the lack of an effective, affordable beginner's telescope. Something such as a 4-inch short-focus reflector might have sufficed in the past; the Meade ETX refractors are perhaps the first innovative beginner's telescopes for the present generation. And Meade surmounted significant challenges to produce them: Rather than churning out merely a good set of optics, they provide a user-friendly mini-observatory for the computer age.

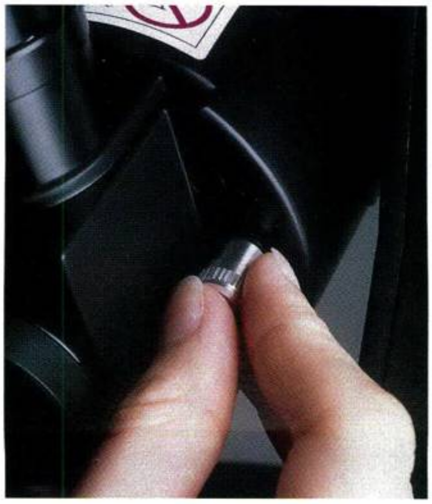
Complexity on the engineering side translates into pure simplicity when the telescopes are unboxed. I tested the ETX units with the aid of an optional accessory, Meade's #882 Standard Field Tripod (list: $99). The tripod sets up like a heavy camera tripod, with lightweight aluminum legs and snap-locks to adjust height. A plastic accessory tray holds up to eight eyepieces and features a clip for the keypad. While one might initially hesitate at the lightweight design of the tripod, the system held up quite well during a moderate wind. Setting up the telescope is as simple as unfolding the tripod, attaching the base of the scope with two long thumbscrews that are supplied with the tripod, inserting six AA batteries into a compartment in the scope's drive base, and attaching the hand paddle. After these few steps, and after reading the introductory material in the owner's manual, prospective users of the ETXs are ready to step outside and initialize their scopes for observing.

A word about the manual: in a world made murky by poorly written, ambiguous owner's manuals, Meade's ETX effort stands out for its clarity, helpful and well-labeled pictures, and hints for beginners contained in boxes scattered throughout. A single addendum sheet listing two corrections was supplied as an insert. The manual presents a "quick-start guide" for those who wish to lunge into action, a well-labeled diagram of the telescope defining its components and features, and sections on the different ways the scope can be used. The telescopes are operational in a variety of ways: manually with or without "Autostar" (the name given the computer system, database, and hand paddle), in numerous Autostar modes that include guided tours of objects or the ability to slew to any of the 1,471 objects in the menus, or in advanced ways that include terrestrial viewing. For this last option, a clever flip-mirror is included so that users can turn a knob enabling upright viewing of scenery, birds, or other targets without contorting their necks.

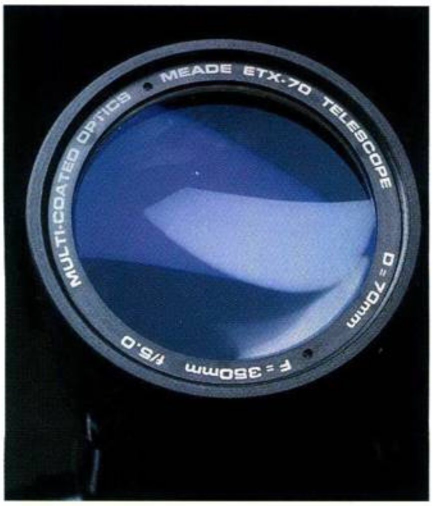
I spent about 15 minutes reading through the basics of the "getting started" section of the manual, attached the ETX-70AT to the tripod, loaded the scope with batteries, and took it outside for a test run. I considered this first encounter a rigorous test because I read only the basics, as I assumed many might do, before getting started. I also set up the tripod on my asphalt driveway, which is not precisely level, and followed the instructions for initializing the Autostar. I placed the telescope in its "Alt/Az Alignment Home Position," with the tube horizontal, declination at 0°, and aimed it, as instructed, roughly northward toward Polaris. The whole key to the telescope, the interface by which one controls it, is the paddle. It consists of an LED screen at top and 10 keys arranged in a trio below the screen ("Enter," "Mode," and "Go To" keys), four cursor keys in a circular pattern that allow moving the telescope, and three keys at the bottom, up, and down arrows that allow choosing options and a "speed" key that allows changing the rate of the tele-



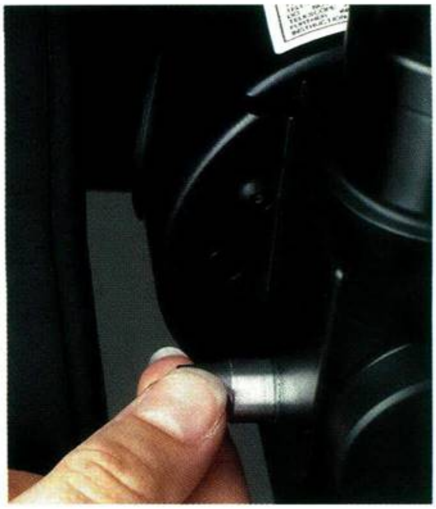
The "Autostar" hand paddle allows ETX users to control modes of the telescope and to use the scope manually as well as automatically.



The ETX focusing knob is tucked inside the right edge of the eyepiece holder. The knurled screw is small; grasping it can be difficult.



The efficiency of the ETX refractor design comes from using the same parts for both models; only different lenses are employed.



A cleverly designed "flip mirror" knob on the left side of the eyepiece tube allows a quick conversion to viewing terrestrial sights.

ON
3X
OFF
AUX
MPUTER CONTROL
17
13
11

The business end of the base contains the power switch and connections; amazingly, the whole thing runs on six AA batteries.

scope's slewing. The keys have multiple functions that are well explained in the manual and in automated instructions that scroll across the LED screen.

To initialize the scope, enter the date, time, whether or not daylight savings time is in effect, and observing location, and then proceed to alignment. In the simplest setup method, the telescope initializes itself by aiming at two bright stars; it then knows where it's aiming and can find the other objects by simple offsetting. Obviously the scopes are low-power, wide-field systems, but I had some degree of skepticism that the ETX would arrive on target at these alignment stars because it was only roughly aimed north and set on a non-ideal surface. With the 25mm eyepiece in place, I continued the setup and requested Vega as a defining star; indeed, the telescope slewed over very close to Vega, within less than a field of view away. I manually slewed the scope to center the bright star and continued with another rough test: using Altair as the second alignment star. Ideally, one would choose two stars that are widely separated to increase the accuracy of alignment. But I wanted to see how the scope would do under trying circumstances. The scope found Altair, placing it just above center in the eyepiece. I slewed it down very slightly to the center of the field, completed the alignment procedure, and proceeded to put the scope through its paces.

Even with such a simple alignment procedure, the scope performed as advertised. I chose two dozen objects widely scattered across the early autumn sky. I commanded the scope to go to the Ring Nebula, the Andromeda Galaxy, the Double Cluster, NGC 457, the Dumbbell Nebula, the Veil Nebula, the moon, Neptune, Albireo, Polaris, and many more. With the low-power eyepiece, every object was either well centered or the object was in the field but slightly off center and required only a momentary tap of a slewing button to exactly center it. Pretty impressive performance for such rough alignment and initial stars that weren't ideal; repeating the procedure with a more level surface and widely separated stars — Vega and Capella — later in the evening produced results that were slightly better. The telescope had advertised that with easy alignment it could reliably find object after object with the

A SIDE-BY-SIDE COMPARISON

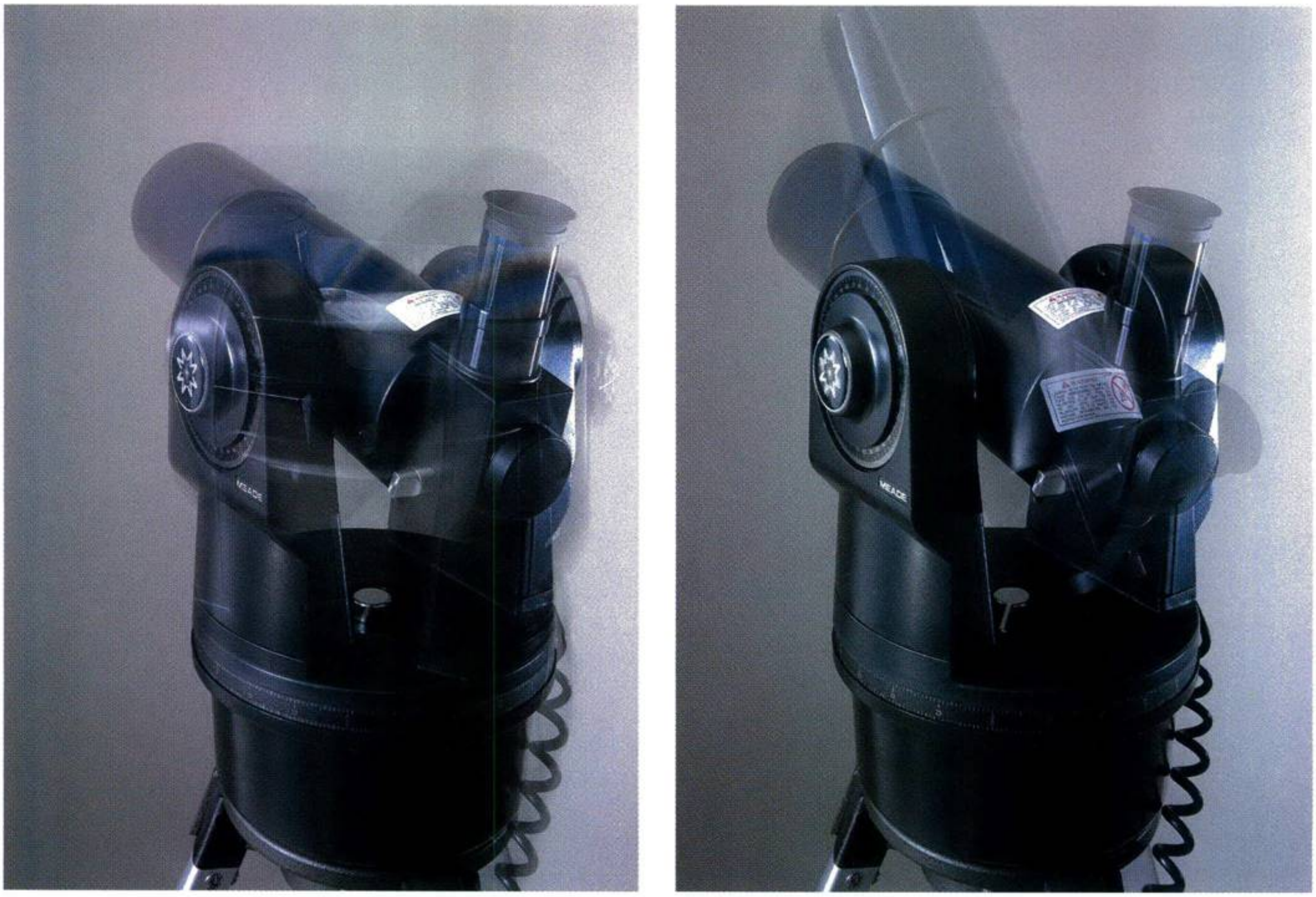
ETX-60AT Telescope with Autostar Hand Controller

Achromatic refractor, multicoated surfaces
Clear aperture: 60mm (2.36")
Focal length: 350mm (13.78")
F/ratio: 5.8
Near focus: 15'
Resolving power: 1.9"
Limiting magnitude: about 11.2
Eyepieces supplied: 25mm MA and 9mm MA, 1¼" barrels, yielding 14x and 39x
Dimensions: 15.9" by 7" by 9"
Weight: 5.8 lbs.
List price: $299 ("street price" may vary)

ETX-70AT Telescope with Autostar Hand Controller

Achromatic refractor, multicoated surfaces
Clear aperture: 70mm (2.76")
Focal length: 350mm (13.78")
F/ratio: 5
Near focus: 17'
Resolving power: 1.6"
Limiting magnitude: about 11.5
Eyepieces supplied: 25mm MA and 9mm MA, 1¼" barrels, yielding 14x and 39x
Dimensions: 15.9" by 7" by 9"
Weight: 5.9 lbs.
List price: $349 ("street price" may vary)

Meade Instruments Corp., 6001 Oak Canyon, Irvine, CA 92618 (949) 451-1450, www.meade.com.



After simple alignment routines, the ETX refractors accept commands to slew toward objects first in R.A. and then declination.

press of a couple buttons, and its performance backed up these claims. It was impressive that you could go out and even after being relatively carefree about aligning the scope, it still worked. "Training the drive," a simple procedure described in the manual, should be done every three to six months to maintain a high level of pointing accuracy. The ETX-60AT functioned exactly the same way.

After using the telescope for a few hours, the sea change in how technology will affect beginning observers struck me hard. When I started out as a teenager exploring deep-sky objects with a pair of 7x50 binoculars — comparable in light-gathering power to the ETXs — a laborious learning curve came attached to discovery. Sure, spreading maps everywhere and learning the sky in a detailed way impressed a good knowledge of the heavens into regular observers; by contrast, the potential of the computerized generation is startling. With the ETX, in a matter of minutes, I could see two or three dozen objects in rapid succession, finding them effortlessly and comparing their appearances much more effectively because they were so easy to locate. Who knows what intrepid deep-sky observers will emerge from this kind of technology when their thoughts can focus on the objects and what they look like more so than on the tricky star-hopping tests of simply finding them?

With the telescope up and running, users can explore a variety of objects: solar system, deep sky, constellations, or even satellites. After scrolling through a list displayed on the LED screen, you simply choose "enter" to highlight an object and then "go to"; the scope then slews with its relatively quiet whizzing and, when the object is centered, signals by issuing a little beep.

Both the 60mm and 70mm models performed well optically, particularly considering that they are low-priced achromats aimed at beginners. Images were sharp and detail good, but an achromatic lens is inherently imperfect; the very edges of the field were slightly blurry, not yielding an absolutely flat field like the one produced by a much more expensive apochromatic lens. The two-element lens also showed some color fringing on very bright objects such as the lunar limb.

Meade offers a small array of accessories for the ETX refractors including eyepieces, filters, a carrying case, a finderscope, heavier tripods, and even software that allows attaching the scope to a PC and linking it to a database of more than 10,000 sky objects. Several paths of deeper involvement with the ETX line are available to beginners whether they enjoy deep-sky observing, lunar and planetary work, or photography.

After using the ETX refractors, it's clear that the telescopes work effectively and reach their goal of bringing introductory astronomy into a new phase. With their modest price tags, they are highly recommended for beginning observers, who will not only discover that they make finding and enjoying sky objects easy, but they bring a new kind of fun to spending nights under the stars.

Dave Eicher is managing editor of Astronomy *and has been an avid observer for 24 years.*

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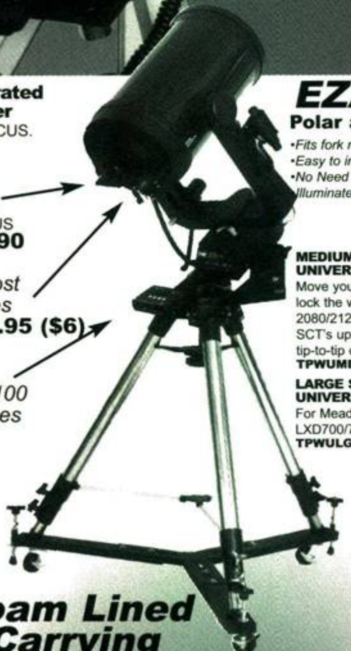

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Pictor, Dorado, and Mensa

This trio of southern constellations hosts the closest galaxy to the Milky Way.

by Tom Polakis

Once you move beyond Crux and the bright stars of Centaurus, the southern sky has a striking lack of conspicuous star patterns. Nowhere is this more evident than in a trio of constellations on display from the tropics and the Southern Hemisphere during the early months of the year. Pictor, Dorado, and Mensa contain no star as bright as magnitude 3.0 and just four stars brighter than magnitude 4.0. Yet this apparently barren area holds a wealth of impressive deep-sky objects for backyard observers.

The easiest way to find this region is to start with Canopus, the brightest star in neighboring Carina and, at magnitude –0.7, the second brightest star in the whole sky. Pictor the Painter begins just a few degrees west of Canopus. Third-magnitude Alpha (α) Pictoris lies at the southern end of a string of three moderately bright stars with the northern end marked by Beta (β) Pictoris.

The star pattern that makes up Dorado the Swordfish includes a winding chain of five 3rd- through 5th-magnitude stars. Among these is Beta Doradus, a Cepheid variable star that oscillates between magnitude 3.5 and 4.1 over a period of about 10 days. Mensa the Table Mountain, whose brightest star glows at 5th magnitude, lies south of Dorado.

Dorado and Mensa would hardly rate a second look if not for the Large Magellanic Cloud (LMC) — the closest nondwarf galaxy to our own and a stunning sight whether viewed with the naked eye, binoculars, or a telescope. Named after the Portuguese explorer Ferdinand Magellan, who first circumnavigated the globe in the 16th century, the LMC ranks among the finest objects in the sky.

Before diving into the LMC, let's begin our tour well to the north. **Kapteyn's Star** lies in Pictor, just south of the constellation's border with Columba. Only 13 light-years away, this star has the second highest proper motion after Barnard's Star, moving to the southeast at 8.7" per year. The ruddy hue of this cool star should help you spot its 9th-magnitude glow.

Pan 2° west of Alpha Doradus to find the bright spiral galaxy **NGC 1566**. This galaxy belongs to the Dorado Galaxy Group and lies 55 million light-years away. Its gracefully symmetric spiral form shows up easily in the high-power eyepiece of a 10-inch telescope. Look for a bright emission region that appears like a faint star at the north end of the western spiral arm.

Just 10' separate **NGC 1549** and **NGC 1553**, an interacting pair of galaxies in the Dorado Group that lies 1° southwest of NGC 1566. The northerly NGC 1549 shows up bright and round, with a 2.5' diameter and a bright middle. NGC 1553 appears 2' across and twice that long and also has a blazing core.

Scan half a degree north of 5th-magnitude Kappa (κ) Doradus to locate the four-armed barred spiral galaxy **NGC 1672**. In a 13-inch telescope, the east-west bar fades rapidly as you move away from the bright stellar core. One of the galaxy's arms can be seen curling north from the east end of the bar.

Straddling the border between Dorado and Mensa lies the pièce de résistance of our tour: the **Large**

Artwork at left by *Astronomy*: Kellie Jaeger

Magellanic Cloud. A magnificent target even for the naked eye, the LMC boasts a luminous bar measuring 5° by 1° that's similar in brightness to the Scutum Star Cloud. The intensity drops rapidly into a less defined oval haze 6° by 4° across and closer in appearance to the winter Milky Way. NGC 2070, the Tarantula Nebula, appears as a 10'-diameter bright spot 1° north of the bar's eastern end.

Astronomers classify the LMC as a nearly face-on barred spiral galaxy that lies approximately 170,000 light-years from Earth. The LMC and its smaller cousin, the Small Magellanic Cloud (SMC) in Tucana, show signs of interacting both with each other and with the Milky Way. The Magellanic Stream, a band of neutral gas that extends 10° by 100°, runs through the LMC, SMC, and the disk of our galaxy.

The best telescopic perspective on the Large Magellanic Cloud comes by viewing objects of the same classification together. Comparing globular clusters, open clusters, and nebulae will prove more rewarding than a haphazard jump around the LMC. Use a detailed star atlas, such as *Uranometria 2000.0* or the *Millennium Star Atlas*, to help hop from one object to the next in these confusingly packed fields.

The LMC claims just 13 globular clusters, less than 10 percent the number found in the Milky Way. These collections of tens of thousands to hundreds of thousands of stars formed early in the history of the universe, more than 10 billion years ago.

Look toward the center of the LMC's bar to find the bright globular **NGC 2019**. This 11th-magnitude object stands out thanks in part to its sharply defined core.

An even brighter globular lies in the western part of the bar. **NGC 1835** at first appears round and a bit more than 1' across, but a closer look shows faint extensions to the east and west that bring its length to 3'. Two open clusters, NGC 1828 and NGC 1830, can be seen less than 6' to the west.

Despite the relative lack of globulars, the LMC boasts a class of objects unlike any seen in our galaxy. They appear remarkably similar to globular clusters but they formed within the last few billion years, so they have a much higher proportion of young, blue stars. Most astronomers classify these objects as rich open clusters, though in a telescope they tend to look more like blue globulars.

NGC 1651 lies 0.6° northwest of Mu (μ) Mensae and appears detached from the western edge of the LMC's visible halo. This 2'-diameter fuzzball looks round and broadly concentrated.

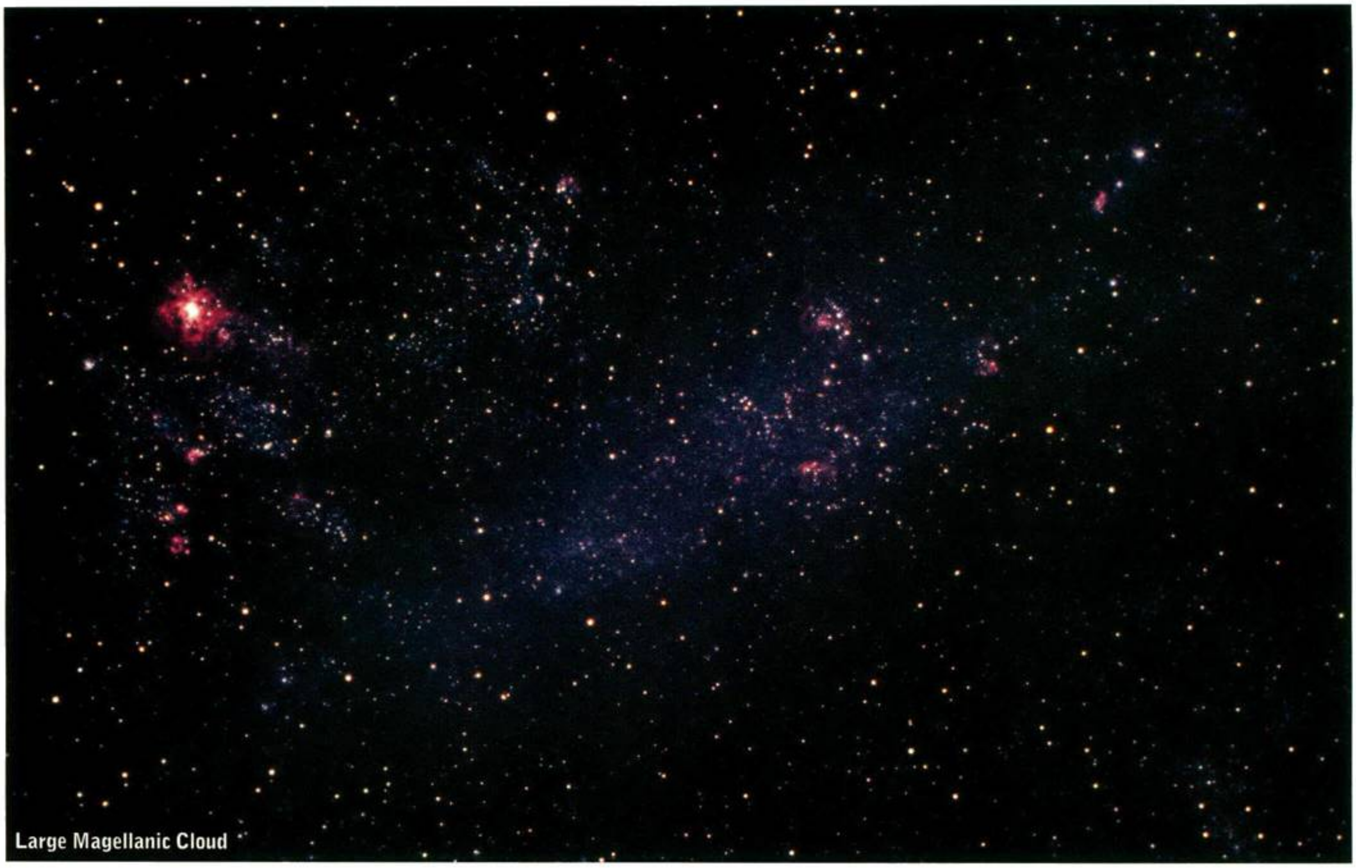
Scan half a degree southwest of Theta (θ) Doradus and you'll come to **NGC 1846.** A 16-inch telescope at high magnification begins to resolve some 16th-magnitude stars across the center of the 2.5'-diameter ball.

A striking object lies near the northern edge of the LMC's visible glow. **NGC 1978** measures 2' by 1' in the eyepiece, looking for all the world like a bright elliptical galaxy. Although difficult to resolve, this elongated cluster appears grainy when viewed in good conditions.

NGC 2154 resides northeast of the visible extent of the LMC. Slightly larger than 1' in diameter, it shows a dozen members at the limit of most backyard instruments.

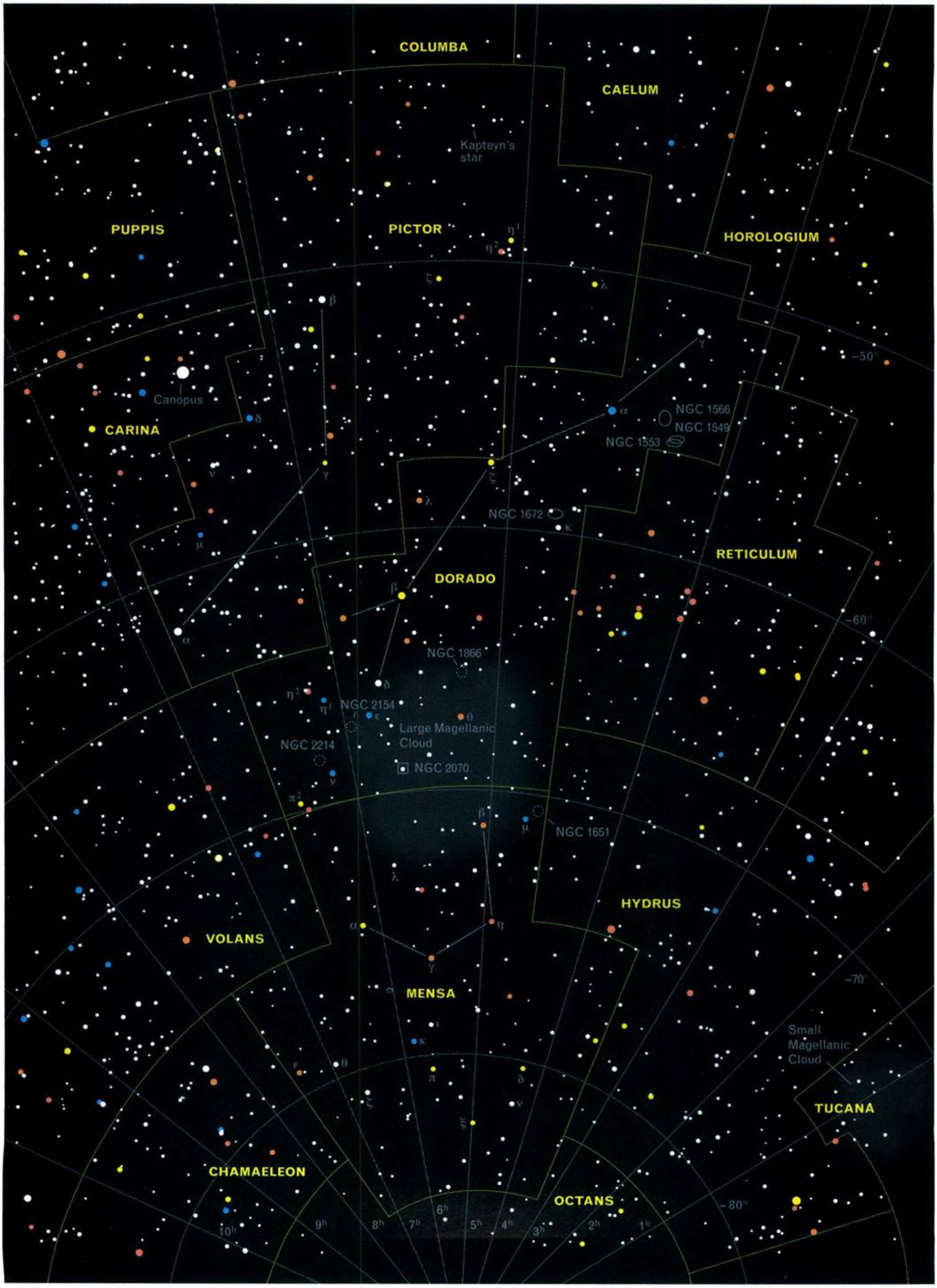
Turning now to the more traditional type of open cluster, **NGC 1755** can be found on the western end of the LMC's bar. It shows some 20 13th- and 14th-magnitude stars packed into an area 2' across with a strong background glow. The companion cluster NGC 1749, just 2' to the west, is another sprinkling of faint stars against a gleaming backdrop.

Pan 1.4° east along the bar to find one of the more massive open clusters



Large Magellanic Cloud

Alan Dyer


COLUMBA
CAELUM
Kapteyn's star
PUPPIS
PICTOR
HOROLOGIUM
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η²
ζ
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Canopus
CARINA
δ
α
NGC 1566
NGC 1549
NGC 1553
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NGC 1672
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RETICULUM
DORADO
β
α
−60°
NGC 1866
δ
η²
η¹
NGC 2154
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Large Magellanic Cloud
NGC 2214
NGC 2070
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π²
β
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NGC 1651
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HYDRUS
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VOLANS
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MENSA
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ι
κ
Small Magellanic Cloud
ε
θ
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TUCANA
CHAMAELEON
OCTANS
−80°
6h
10h
9h
8h
7h
5h
4h
3h
2h
1h

in the LMC, **NGC 1850**. A 6-inch telescope brings out roughly 50 stars glowing at magnitude 13 and 14 in a circular area 3' across. The prominent clump of stars on the western edge constitutes a companion cluster designated NGC 1850A.

From NGC 1850, sweep 3.3° north to reach **NGC 1866**. This cluster's brightest stars glow at 15th magnitude, so larger apertures can reveal hundreds of stars. At magnifications of 300x and higher, NGC 1866 appears stunning.

NGC 2004 contrasts nicely with the previous clusters. Located 2.5° southeast of NGC 1866, the 2'-diameter cluster contains a couple dozen easy-to-see stars. It shows a bright core with little background glow from unresolved stars. At 8 million years old, it's one of the LMC's younger clusters.

NGC 2070

Luke Dodd

You may have a hard time keeping focused on **NGC 2100** because it lies within half a degree of the Tarantula Nebula in one of the most spectacular telescopic fields in the sky. Like NGC 2004, this cluster resolves into a modest number of stars covering an area 2' across.

To the west of the LMC's visible glow sits **NGC 2214**. It appears as a bright haze, but its stars remain hard to resolve except at the edge. Look for three fainter clusters lying within 10' to the south and east.

We've saved the best class of LMC objects for last. Dozens of bright emission nebulae scatter across the galaxy's face. Try using a nebula filter for the best views.

Tiny **NGC 1714** lies on the western edge of the LMC. Although it appears only 1' across, its high surface brightness permits a detailed view. Expect to see a circular glow with a bright northern rim.

Sweep 0.7° northeast and you'll land on **NGC 1763**, a complex of half a dozen emission nebulae packed into an area 15' in diameter. A clumpy haze that measures 4' by 2' across at the center of this busy field responds well to an Oxygen III filter.

One of the more spectacular emission nebulae in the LMC lies near the galaxy's heart. **Henize 119** looks similar to a barred spiral galaxy when

Deep-Sky Objects in Pictor, Dorado, and Mensa

Object	R. A. (2000.0)	Dec.	Mag.	Size	Type	Notes
NGC 1549	4h15.7m	–55°36'	9.5	5.4' by 4.8'	Gal	SAB0
NGC 1553	4h16.2m	–55°47'	9.1	6.3' by 4.4'	Gal	SA0
NGC 1566	4h20.0m	–54°56'	9.4	7.1' by 4.8'	Gal	SA(s)bc
NGC 1651	4h37.5m	–70°35'	12.7	2.5'	OC	
NGC 1672	4h45.7m	–59°15'	9.8	6.2' by 3.4'	Gal	SAB(s)bc
NGC 1714	4h52.1m	–66°56'	—	<1'	BN	
NGC 1755	4h55.0m	–68°11'	9.9	2.6'	OC	
NGC 1763	4h56.8m	–66°24'	—	5' by 3'	BN	
NGC 1835	5h05.2m	–69°24'	10.1	1.2'	GC	
NGC 1846	5h07.6m	–67°28'	11.3	2.8'	OC	
NGC 1850	5h08.5m	–68°46'	9.0	3.4'	OC	
Kapteyn's Star	5h11.7m	–45°01'	8.86	—	Star	Large proper motion
NGC 1866	5h13.5m	–65°28'	9.7	4.5'	OC	
Henize 119	5h18.7m	–69°13'	—	16' by 13'	BN	
Large Magellanic Cloud	5h23.6m	–69°45'	0.4	650' by 550'	Gal	SB(s)m
NGC 1962	5h26.4m	–68°50'	—	—	BN	with NGCs 1965, 66, 70
NGC 1968/74	5h27.4m	–67°28'	—	13' by 12'	BN	
NGC 1978	5h28.6m	–66°14'	10.7	3.9'	OC	
NGC 2004	5h30.6m	–67°17'	9.6	2.7'	OC	
NGC 2019	5h31.9m	–70°10'	10.9	—	GC	
NGC 2070	5h38.6m	–69°05'	—	30' by 20'	BN	Tarantula Nebula
NGC 2074	5h39.0m	–69°30'	—	—	BN	
NGC 2100	5h42.0m	–69°14'	9.6	2.8'	OC	
NGC 2154	5h57.5m	–67°15'	12.1	2.3'	OC	
NGC 2214	6h12.8m	–68°16'	10.9	3.6'	OC	

Object: Designation in Messier, NGC, or other catalog. **R. A. (2000.0) and Dec.:** Right ascension and declination in epoch 2000.0 coordinates. **Mag.:** Visual magnitude. **Size:** Size in arcminutes. **Notes:** Hubble type for galaxies.

The Swordfish

"I never lost a little fish —
yes, I am free to say,
It always was the biggest fish
I caught that got away."
Our Biggest Fish
Eugene Field (1850–1895)

Lions and tigers and bears (oh my!) may seem to most people just a pleasant little ditty from *The Wizard of Oz*, but any skywatcher could be forgiven for thinking the verse applies to his or her hobby. After all, if you head outside in the Northern Hemisphere on most any night, the sky will be filled from horizon to horizon with creatures great and small.

But observers of the far southern sky have few opportunities to visit the celestial zoo. Most of those constellations were named not for the beasts and legends of European antiquity but instead for the things that excited the European explorers who systematically charted the southern sky for the first time. Dutch navigators Pieter Dirkszoon Keyser and Frederick de Houtman introduced Dorado the Swordfish to the world at the close of the 16th century, one of a dozen new constellations they invented while mapping the southern sky.

We have Nicolas Louis de Lacaille to thank for our other two constellations. Lacaille spent the early 1750s observing the sky from the Cape of Good Hope in southern Africa. Most of the constellations he created depicted instruments of science or the arts. That's the case with Pictor the Painter, which Lacaille visualized as a painter's easel and palette.

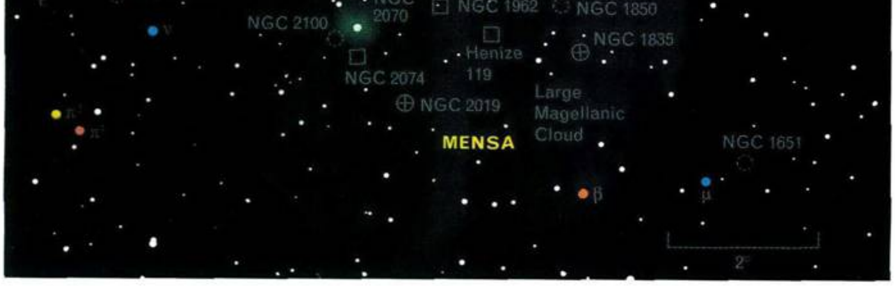
Mensa the Table Mountain, however, breaks this pattern. Lacaille named it for the flat-topped bluff known as Table Mountain, which overlooks the Cape. That makes Mensa unique as the only constellation to depict a specific terrestrial feature (though some writers associate Eridanus with the Nile River). Why elevate Table Mountain to this status? Apparently Lacaille often noticed clouds topping the bluff, so he placed Mensa where the Large Magellanic Cloud would look like mist above the constellation. — *Richard Talcott*

viewed through a 13-inch scope and a narrow-band filter. Two "arms" extend from the eastern and western ends of the oval central region.

Scan half a degree to the northeast and you'll land on **NGC 1962**. It appears at first as a faint, circular haze 7' across, but closer inspection reveals that the northern rim consists of three enhancements in an arced arrangement. A faint "tail" extends 20' eastward from the southern edge.

NGC 1968/74 lies 1.4° north of NGC 1962. It's the brightest of four nebulae in a 20'-long arc. Each of the four contains small associated star clusters that makes for a magnificent sight.

NGC 2070, the Tarantula Nebula, ranks as the most detailed emission nebula in the sky — an impressive feat considering its distance. With a diameter of 1,000 light-years, the Tarantula would span 20° if it were as close as the Orion Nebula. A hotbed of ongoing star formation, the nebula has churned out more than 3,000 stars that now reside in the central open cluster known as R136. Many of these stars are among the most massive, luminous, and hottest stars known.



Even in a small telescope, the Tarantula shows a spectacular array of loops and filaments that requires little deep-sky observing technique. The brightest concentration occurs around R136, which shows several dozen bright stars over a region 1' across. The longest filament begins near the center and extends 7' to the south before turning east and looping that same distance around the nebula to the north. Two well-defined hollow regions with intricate surrounding laces lie north of the central cluster. All this detail — and much more — crowds into an object that appears just 15' across.

Our tour of the LMC concludes with a stunning field. Pan a little less than half a degree south from the Tarantula Nebula to **NGC 2074**. Although a bright object in its own right, NGC 2074 acts as a guide to a spectacular field of nebulae and clusters. Intense star clouds shine to the west, while a multitude of small emission regions highlighted by NGC 2080 glow to the south. Fields like this one make any hope at a complete survey of the LMC seem pretty futile. ■

Tom Polakis is an aerospace engineer who lives in Tempe, Arizona. His favorite astronomical pursuits are deep-sky observing and photography.

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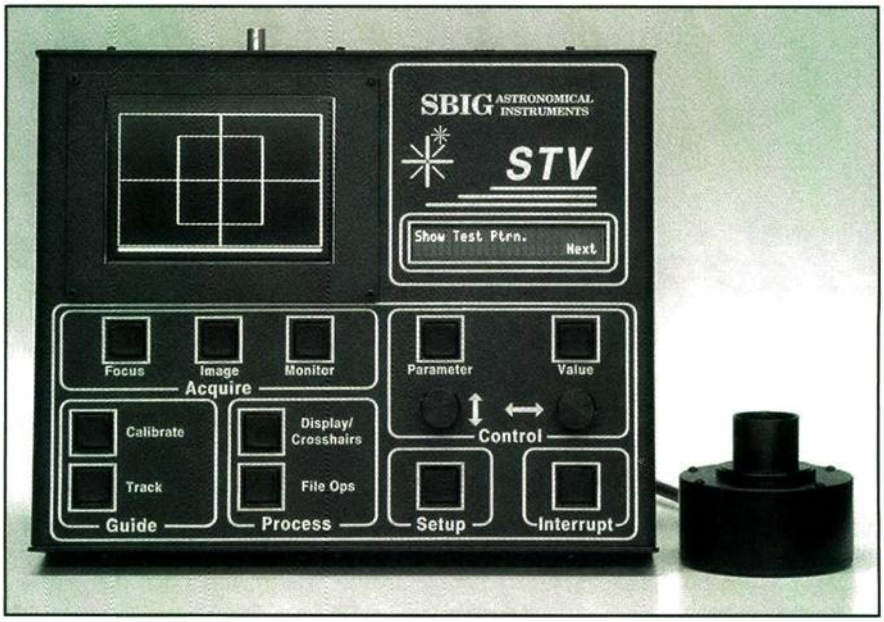
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Sharpen Your Images

You can brighten galaxies with a larger telescope, but bigger may not provide better resolution.

by Bob Berman

I WAS RECENTLY TUTORING COLLEGE STUDENTS WHEN WE were treated to the kind of exquisite views we may never forget. It was a clear night. The students gathered eagerly as I prepared my demonstration. Swinging my 12-inch f/6 reflector toward Saturn, I was wondering how bad the "seeing" would be when something amazing happened.

Saturn didn't shimmer or flicker. There stood sharpness seemingly right out of Hubble, detail rivaling Voyager's famous approach pictures. The Cassini Division, that inky gap in the planet's rings a half arcsecond (0.5") across looked broad enough to drive a truck through. I quickly swung the telescope to nearby Jupiter. We gasped. Jovian clouds appeared so intricate that sketching all of them would have been impossible.

In three dozen years of observing I'd seen it this good just a couple times. Here in the Catskills, transparency is typically excellent but seeing is often poor. I'm used to it, and tend to point my scopes at the Orion Nebula and other objects that elicit oohs and wows even without fine resolution. During the past decade while teaching at Marymount College in New York and nearby secondary schools, I've used four telescopes ranging from a 3-inch refractor to a 16-inch Cassegrain. During the years I had almost forgotten that my scopes can deliver spectacular detail when the atmosphere cooperates.

Great experiences are a reminder that when it comes to planetary observation, the best resolution possible is the aim of every amateur. Resolution, the ability to discern fine detail, usually is expressed as the smallest angle between two point objects that produce distinct images. Yet the issue often is clouded in confusion — and cries out for an explanation.

The Power Pitfall

Compared to the naked-eye view, a telescope's image is bigger and often brighter. Is it also sharper? No, not usually, because of an issue separate from, but related to, resolution — image clarity. A television does not approach the clarity of normal human vision. Likewise, most of us are used to squinting at telescopic images that are less clear than grainy reruns of *NYPD Blue*. We accept it with a shrug, like taxes.

Beginners often assume they can enhance the quality of a telescope by increasing its power. Unfortunately, it's a mirage. The illusion vanishes when high-power views boil down to staring at big smudge-balls. Excessive magnification blurs the already blurry picture, mostly by amplifying the effects of air turbulence. The ability to detect fine detail is theoretically proportional to telescope (or eye) diameter; however in my corner of the world where atmospheric conditions vary, telescope images usually don't get sharper with apertures greater than 8 inches. A 12-inch telescope can achieve a resolution of about 1", which is about as good as the atmosphere gets. At places such as Cerro Tololo in Chile, larger apertures yield sharper images because that area's stable atmospheric conditions promote excellent seeing. The Hubble Space Telescope's 2.4-meter mirror provides images 10 times sharper than the best ground-based telescope typically achieves without special adaptive optics. Why? Because Hubble operates above Earth's atmosphere.

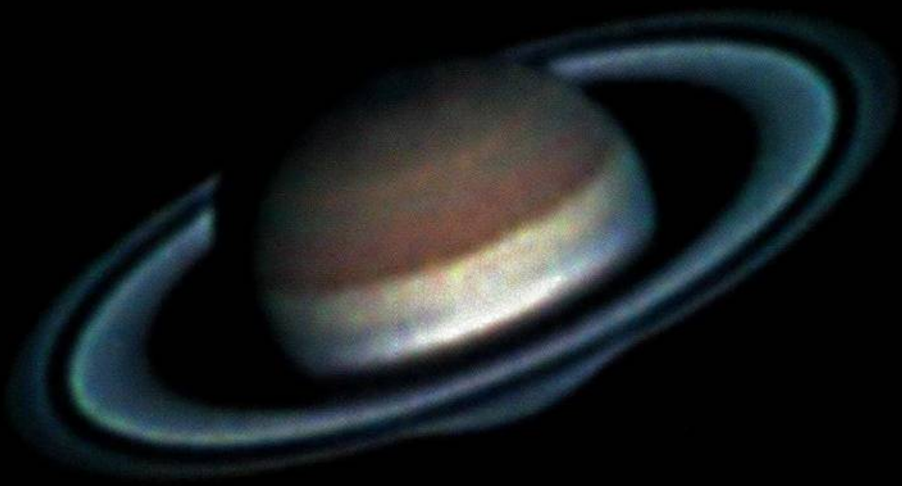
Down here, when seeing is moderate to poor (most of the time in most of the world), a larger reflector — particularly one greater than 8 inches — usually produces a poorer image because it intercepts larger chunks of blurry atmosphere.

Still, most amateurs prefer bigger instruments because of their ability to brighten. Often, cranking up an object's brilliance seems to yield dramatically finer detail, simply because previously invisible structure gets promoted to the visible. For example, with an 8-inch telescope it's virtually impossible to glimpse the spiral arms of the famed Whirlpool Galaxy (M51), but a 16 incher gives whorls of stars. The bigger telescope hasn't provided finer sharpness. Doubling the aperture quadruples the brightness (about 1.5 magnitudes), which raises M51's spiral arms above the eye's threshold of visibility.

The finest 3-inch instrument, such as the old, costly, finely crafted Questar, cannot resolve stars in the famed globular

This photo simulation shows how Saturn would appear with 3-, 6-, and 12-inch telescopes. (The actual views would depend on the quality of the optics, "seeing" conditions, and observing expertise.) John Chumack

All photo illustrations by *Astronomy*: Thomas Ford



12-inch

6-inch

3-inch

cluster M13. Jump to a 6 incher, however, and many of its roughly 1 million stars materialize like magic. The 6 incher sufficiently brightens the cluster's individual stars to make them visible. Charles Messier, observing M13 in 1764, described it as "A nebula which I am sure contains no star." Messier's favorite telescope was a 7.5-inch 104x Gregorian reflector whose optics would be considered inferior by modern standards. Had poor Messier been able to use today's standard 8-inch Schmidt-Cassegrain telescope (SCT), he would have instantly discerned M13's true nature.

Today, the brightness-boost delivered by bigger, high-quality optics can fool neophyte observers into thinking they are experiencing more sharpness than what is actually before them. Such demonstrations make it easy to jump on the brightness bandwagon. Jumping from a 3-inch to a 6-inch telescope is wondrous. Leaping to a 12 incher is intoxicating. The Ring Nebula (M57) abruptly jumps from dimly visible to in-your-face. However, to get a 1-magnitude boost after using a 12.5-inch scope, you'd have to go to 20 inches.

Bigger, Brighter, Blurrier

While brightness is a quantifiable attribute, image sharpness is fuzzy. The fourfold increase in brilliance of a globular cluster — seen first through a 6 incher and then a 12-inch SCT — is immediate and obvious. The quality of the telescope matters little. The seeing matters little. Your site matters little. A larger telescope operated with minimal skill or finesse delivers bigger, brighter images. But now evaluate sharpness through the two instruments. Because blurriness is usually a result of small-scale disturbances in the atmosphere (poor seeing), a bright object with potentially fine detail — lunar craters or jovian equatorial belts — may actually look sharper through the smaller telescope.

Rifling through an attic recently, I came across pencil drawings I had made of Jupiter in 1960 at the eyepiece of my old 2.4-inch refractor. I was amazed — first at how much patience I had as a kid — but also at the wealth of detail I had obviously seen through that tiny instrument. Yes, it's true that refractors, particularly apochromats, are better at conveying detail than modern catadioptric instruments, which use refractive and reflective elements. However, the real story was the amazing sharpness that had poured out of a telescope that most would regard as a starter instrument.

Sometimes, even in New York, it all comes together. Low expectations fly out the window. Suddenly, unpredictably, there it is — images with impact. Planets can take the breath away, even when seen for the thousandth time. Then you learn again that smudginess is not permanent. Even east of the Rockies in the Kingdom of Smudge, the curtain occasionally lifts. Then the cosmos floats in an almost forgotten glory that every backyard astronomer can appreciate. However, on any night it's important to remember that there are a variety of things we can do to sharpen our views.

How to Ruin an Image

Avoid windows. They are made with poor quality glass, so don't put one between your telescope and the sky. Opening a third-floor window won't help because warm indoor air mixes turbulently with cool outside air to produce a carnival of blur. Cart the instrument outside and let it equilibrate for 20 to 30 minutes.

Don't plop the scope on a warm driveway, near a house's foundation that is still radiating the day's heat, or in the midst of a crowd of people (each of us is a 600-watt heater). If you do, the images will be crummy.

Seek uniform temperatures. If you're building an observatory, remember that wood-frame construction is better than heat-retaining cement or block. Roll-off roofs quickly release trapped heat while also offering panoramic sky views. Your scope will cool more slowly in a dome, but a dome offers you better protection from wind.

Find the Best Site

The dominant image-spoiling gremlin is Earth's churning atmosphere. Starlight is slowed by a slight amount in relation to the density of air it passes through, and the density variations are most pronounced at turbulent areas where cold and warm air mix.

Such blobs often occur close to the ground, which is why an image turns horribly blurry just as you feel a gust of warm or cold air. Because of this, you should consider more than just how dark it is or how far it is from city lights. Seek stable temperatures. Grassy expanses are much better than rocky regions because vegetation does not radiate heat during the night to generate warm-air pockets. Since air often changes temperature on slopes, hilltops are better. Being near a large body of water often has a stabilizing effect because water heats and cools more slowly than land. Some of the best seeing is on ocean islands, but even a nearby lakeside can greatly help.

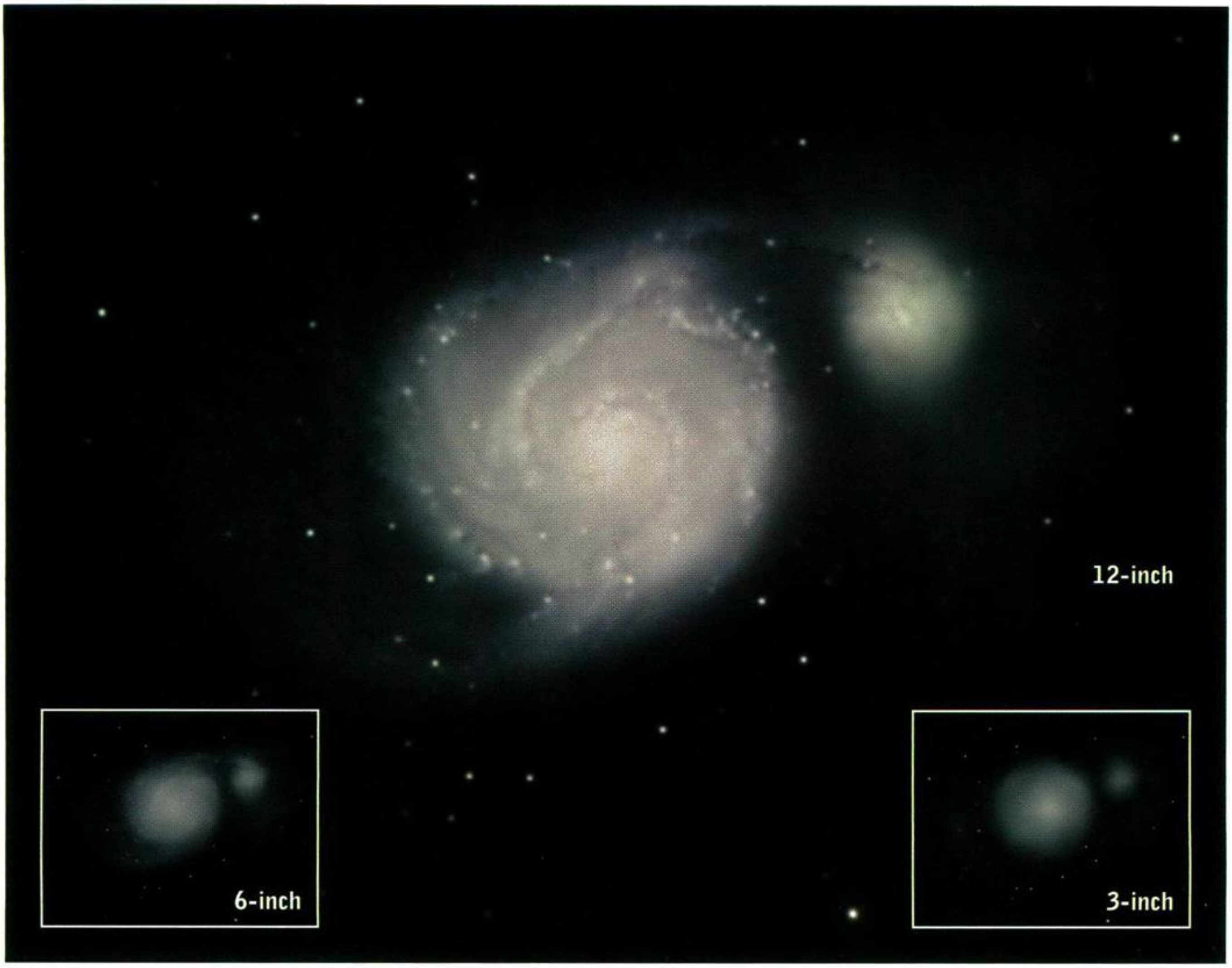
Good transparency and good seeing do not usually go hand in hand. A light mist or fog – signs of poor transparency – often is the signature of a homogeneous atmosphere that offers good seeing. During a recent night of incredible seeing, a faint glow surrounded bright stars and planets, a condition sought-after for centuries by generations of planetary observers. – *B. B.*

Eyepiece Advice

Next, select eyepieces with care. If everything else is working well, a cheap eyepiece can introduce smudgy color fringes that degrade an otherwise excellent image. Also, planetary detail often calls for the highest power that conditions can accommodate. High-quality 2x or 3x Barlow lenses transform an f/6 telescope into an f/12 or f/18 instrument, respectively, so an eyepiece used in tandem with a Barlow will yield a correspondingly higher magnification. A Barlow will add more optical surfaces into the light path, scattering more light, but this disadvantage is somewhat offset by preserving good eye relief. In terms of eye relief, it's easier and more comfortable to use a 20mm eyepiece placed in a 2x Barlow than a 10mm eyepiece alone. In this case, high power — 40x for each inch of aperture (320x on an 8-inch scope) — is not excessive if everything else is in order.

Testing . . . One . . . Two . . . Three

Viewed at 100x, Jupiter appears twice as large as the naked-eye full moon. An 8-inch scope brightens stars about a thousandfold. You can take those parameters to the bank. But how do you measure sharpness? A sharp image versus a blurry one is obvious; less intuitive is how to fully achieve



The Whirlpool Galaxy (M51) is transformed with larger apertures, as this photo simulation of 3-, 6-, and 12-inch telescopes shows. (The actual views would depend on the quality of the telescope's optics, "seeing" conditions, and observer expertise.) Robert Gendler

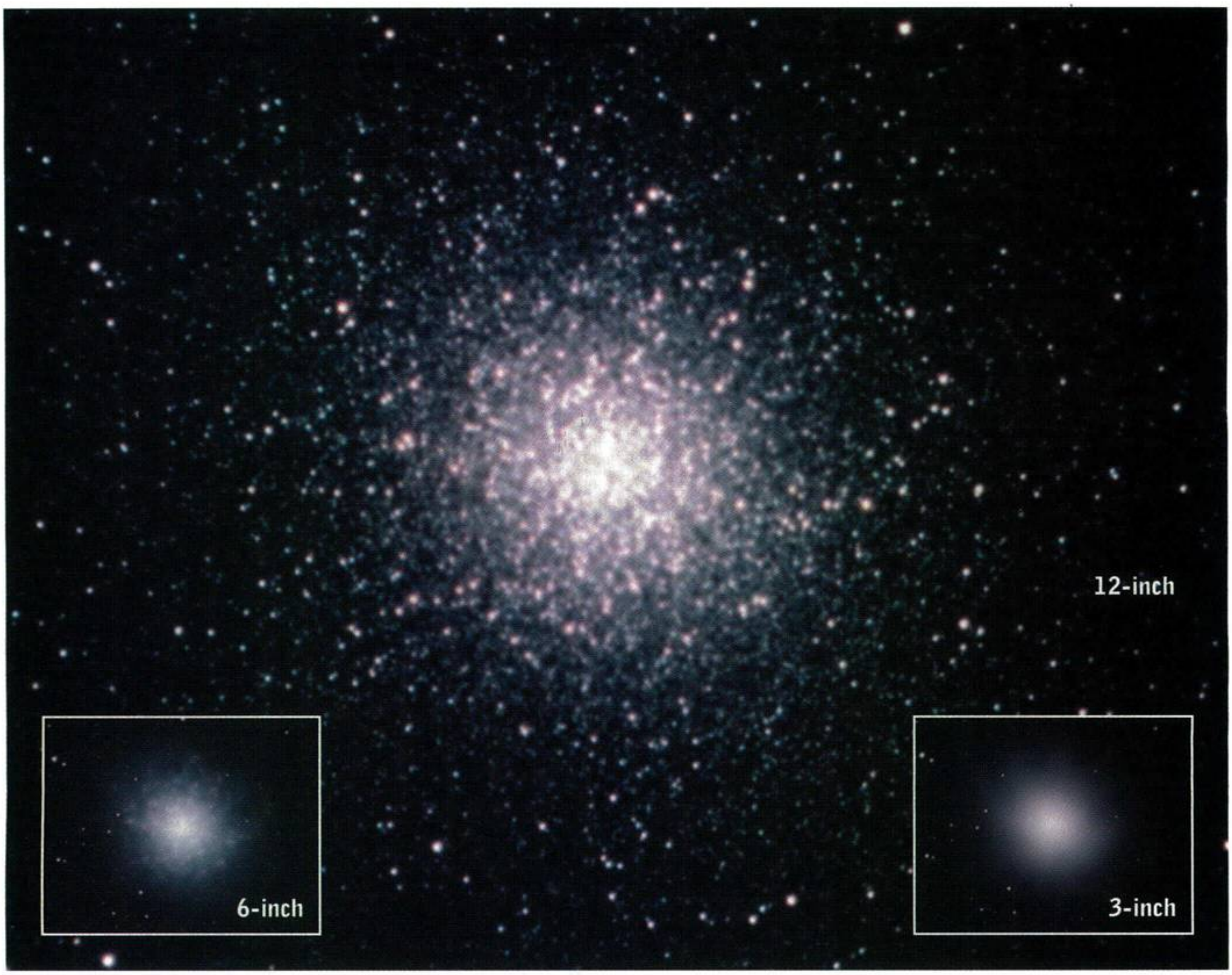
your telescope's potential to bring out detail. If you've collimated your scope and atmospheric seeing is good, use sufficient magnification — namely 2.2 times an instrument's aperture in millimeters. For example, a 60mm refractor can fully achieve its resolution capability at a magnification of 132. (Although many people would say the highest usable magnification is slightly lower — about 120.)

Next, we'll assume your vision is good. "Normal" eyesight varies from person to person, but 20/20 vision typically lets you see a binary star as two individual dots if the separation is 4'. Some people do better than this. An excellent test object is Epsilon Lyrae, the closest bright star to Vega. Epsilon Lyrae is a binary with a 3.5' separation that is readily splittable by the unaided eye for those with superb vision.

Assuming your eye can resolve 4', you can calculate the magnification needed to make any celestial object appear this large. A crater on the lunar meridian 100 miles across, for example, appears about 1.5' wide (because it's roughly 1/20 the moon's 2,160 mile, 30' diameter). To make it meet the unaided eye's 4' requirement, it would have to be magnified just threefold, which is why such large craters show up easily through

Telescope Performance – As Good as It Gets

Telescope Size (inches/mm)	Maximum Usable Magnification	Maximum Resolution (arcseond)	Faintest Star Observable (magnitude)
2.4/60	120x	2.00"	11.6
3.1/80	160x	1.50"	12.2
4/100	200x	1.20"	12.7
5/125	250x	0.95"	13.2
6/150	300x	0.80"	13.6
8/200	400x	0.65"	14.2
10/250	500x	0.50"	14.7
12.5/320	600x	0.40"	15.2
14/355	600x	0.34"	15.4
16/400	600x	0.30"	15.7
17.5/445	600x	0.27"	15.9
20/500	600x	0.24"	16.2



This photo simulation shows how M13, a globular cluster, would appear with 3-, 6-, and 12-inch telescopes. Tony and Daphne Hallas

ordinary 7x binoculars. A power lower than those listed in the accompanying table will not make tiny features large enough to reach the eye's resolving limit for that instrument. Any power larger than those listed may yield blurrier images without increasing detail. But the real problem is immediately obvious. To see all the detail possible, telescopes larger than 8 inches need to use a magnification of 400 or more. Atmospheric conditions rarely permit such high magnification. In practice, 300x is the maximum, which is why your telescope's actual resolution is restricted to roughly 1" — not by the optics but by the unavoidable fact that you are observing on the surface of Earth rather than in space.

Jupiter's largest moons are about 1' in width. Through any 6-inch telescope you should be able to see them as disks rather than dots. Whether or not they really look this way, however, will depend on seeing conditions. The matter is tricky because turbulent air also makes stars and other points of light appear as little disks. Rather than try to determine whether you're resolving a true disk or just viewing a smudge, try splitting double stars. For example, Delta Cygni is considered a test for a 4 incher, while Pi Aquilae or Epsilon Arietis tests a 3-inch scope. Here there is no mistake, because blurry air will make stars dance and smear but not show up as two objects separated by a consistent angle. Other fine tests include Jupiter's many white cloud-top ovals, plus its intricate curlicues and festoons, and Saturn's jet-black Cassini Division in its rings. The detail of shadows cast by lunar mountains on the surrounding terrain is another case where sharpness is obvious. ◼

Collimate as a Habit

Remember that short-focus instruments are more sensitive to misalignment than their longer-tubed cousins. Without proper collimation, stars may have coma or look like seagulls or *V*s. An image from an instrument that is out of collimation will be a study in milky shades of gray, because a dark segment of the image from one part of the mirror will arrive and mix with a bright bit of image from another section, reducing contrast and introducing blur. Proper mirror alignment will give you blacker blacks, whiter whites, and better clarity.

Bob Berman writes Astronomy's *monthly "Strange Universe" column and is author of* Secrets of the Night Sky *and* Cosmic Adventure.

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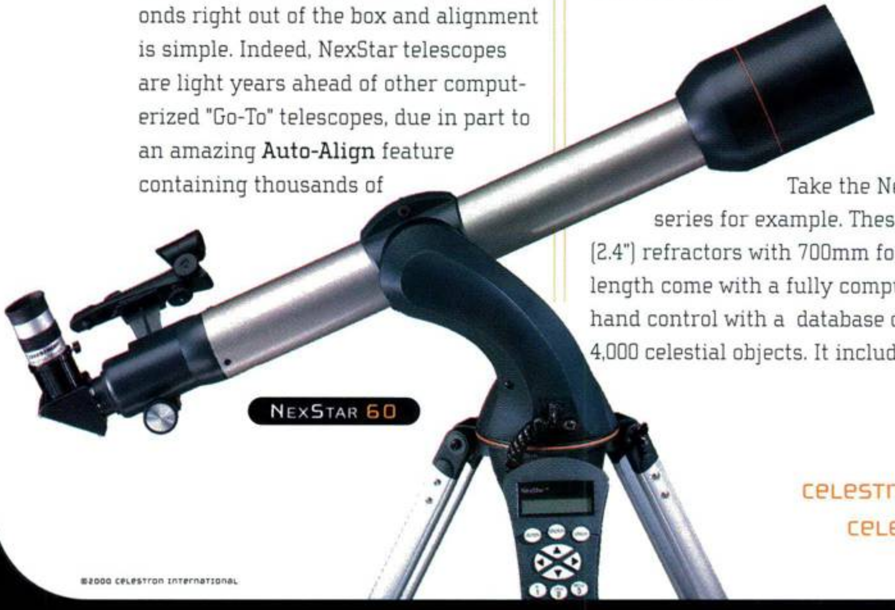

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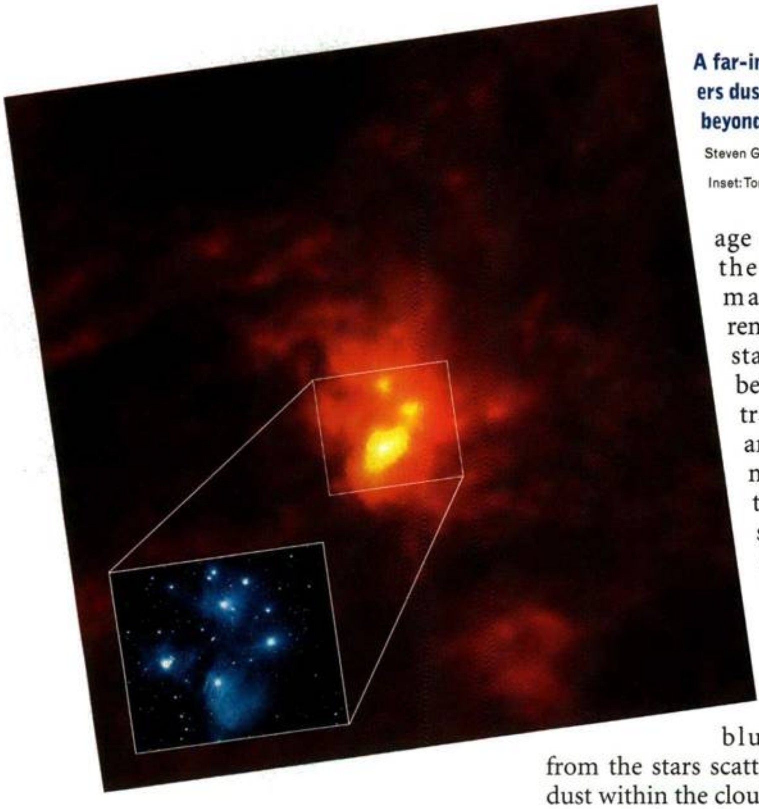

A far-infrared image uncovers dusty gas extending well beyond the Pleiades cluster.

Steven Gibson/IPAC/IRAS

Inset: Tony Hallas

Is the nebula surrounding the Pleiades the same cloud from which the stars were born? — *Lance Leblang, Peoria, Arizona*

Whether seen with the naked eye, binoculars, or a telescope, the Pleiades open star cluster (M45) is one of the loveliest sights the sky has to offer. Only 380 light-years away in Taurus, its brightest stars are easily visible and separable. The beauty of the Pleiades is enhanced by long-exposure imaging, which shows it to be nested within an extensive wispy cloud.

Such open clusters are thought to be born with a full range of stars, from low mass to high. Because high-mass stars evolve and die more quickly than low-mass stars, we can determine the age of a cluster from the brightest, most massive stars that remain. The brightest stars of the Pleiades belong to the B spectral class, suggesting an age of about 100 million years for the cluster. Since B stars are not hot enough to ionize the surrounding cloud to make it glow on its own, the cloud obtains its characteristic blue color as light from the stars scatters and reflects off dust within the cloud.

It was long thought that the dusty gas constituted the remains of the Pleiades' birth cloud. But sophisticated imaging with the Infrared Astronomical Satellite (IRAS) revealed a huge wake in the cloud that extends well to the east of the cluster, showing that the cluster and cloud are not related by birth. Instead, the cloud seems to have blown in from the west and accidentally collided with the cluster at a speed of about 18 kilometers per second (40,000 miles an hour).

A powerful shock wave from a nearby supernova likely produced the wake. Eventually, the Pleiades will emerge from the other side of the surrounding nebula. — *Jim Kaler, University of Illinois. Visit the "Star of the Week" on his website at www.astro.uiuc.edu/~kaler/sow/sow.html.*

Is there anything to be gained from further investigation of the moon? — *Joseph Daudish, Westchester, Illinois*

This question gets to the heart of the pursuit of knowledge and the practice of science and is particularly germane during this time of ever-decreasing federal funding, ever-increasing public misunderstanding and mistrust of science, and constant demands on scientists in all fields to demonstrate the practical benefits of their work.

There is no single correct answer to such a question, however, because knowledge and discovery do not proceed along a simple, linear path. Technology and the tools of science also advance in an unpredictable manner. The moon, with the help of the lunar samples collected by Apollo astronauts, is now studied not only by astronomers, but also by geologists, chemists, physicists, and biologists.

The continued studies may have beneficial results. For example, more detailed study of the moon's enigmatic chemistry and geology may reveal resources such as water or helium that will be critical to the successful operation of future lunar bases. And a more thorough understanding of the origin and evolution of the moon may yield new insights into the origin of Earth itself and the fate of our planet over geologic time. On the other hand, there may be no practical benefit from further investigation of the moon, except to augment our knowledge of the universe.

The beauty of science is that we don't often know where our experiments and explorations will lead. While the depth of our ignorance is profound, if we don't continue to seek,

Secrets of the origin and fate of Earth may lie in our cosmic backyard. NASA/JPL/Northwestern Univ.

learn, and investigate the world(s) around us, we will likely be left wading timidly in the cosmic shallows. — *Jim Bell, Cornell University*

Do comets come from the Oort Cloud or the Kuiper Belt? — *Tomas Serra, Castellgalí, Catalonia, Spain*

Around 1950, Dutch-American astronomer Jan Oort proved from statistics of comet orbits that many comets come from a swarm of objects extending as far out as 50,000 astronomical units (AU) from the sun. (1 AU is the average orbital distance between the sun and Earth.) This group is often called the Oort Cloud, though a more descriptive name would be the Oort Crowd. Further dynamical studies indicate that these comets likely formed in the plane of the solar system and were thrown into the Oort Cloud by close encounters with the giant planets, in the same way that the Voyager spacecraft were deflected to the outer solar system after close passes by the outer planets. The longer-period comets with aphelia — the furthest distance of a body from the sun in its orbit — of thousands of AU come from this source.

Around the same time, another Dutch-American astronomer, Gerard Kuiper, speculated that many icy bodies must have simultaneously formed in the Uranus-Neptune-Pluto region with these planets — remaining stranded there in orbit around the sun. In the 1990s, scientists discovered large numbers of these prisoners of the outer solar system. And just as occasional asteroids are deflected from the main asteroid belt into Earth-approaching orbits, some Kuiper Belt objects are deflected into orbits that bring them inward among the giant planets of our solar system.

Many short period comets as well as so-called Centaurs — such as 2060 Chiron — are examples of such objects. Chiron is especially interesting since it was first cataloged as an asteroid when it was discovered in 1977, traveling through the region between Saturn and Uranus. But in 1988 astronomers observed dusty coma material being thrown off from Chiron and soon realized that it was more like a comet than an asteroid.

In short, comets may come from both the Oort Cloud and the Kuiper Belt. The important thing to remember is that the solar system is full of both rocky and icy bodies left over from the planet-forming period. The difference between comets and asteroids is that comets formed in the cold, outer solar system (roughly Jupiter's distance and beyond) and contain substantial amounts of ice. Regardless of whether they come from the Oort Cloud or the Kuiper Belt, comets also sublimate and emit gas when warmed by the sun. — *William K. Hartmann, Planetary Science Institute*

If radio astronomers on a planet circling Epsilon Eridani used the same search protocols and techniques that we're using in our SETI efforts, would they detect signs of intelligent life on Earth? — *Ray Montello, Seabrook, Texas*

In general, no. The most significant emissions, in terms of power, that leak off our planet are FM radio and television broadcasts. Many TV transmitters burn a hundred thousand watts of power and more, and they're broadcasting 24 hours a day. In addition, since they are plentiful, the Eridanians (should they exist) could be assured of having at least a few sources "aimed" in their direction no matter when they turned their antennae toward Earth.

What would alien radio astronomers think of our Earthly emissions? *Astronomy*: Terri Field

But such emissions would elude scientists on Epsilon Eridani if their experiments were similar to those we currently run on Earth. Even Project Phoenix, which is the most sensitive earthly SETI search, is still a factor of 100 below the sensitivity required to find such emissions. In addition, SETI scientists prefer to look at microwave frequencies, which are 10 times higher than most television signals.

An Earth-like SETI system could, however, detect high-powered military radar systems and the occasional deliberate broadcast (such as the Arecibo demonstration of 1974) at the distance of Epsilon Eridani.

Detecting leakage radiation from other civilizations is sure to be difficult. But radar — such as the aliens might use to track long-period comets — or a deliberate beacon could be readily observed through current methods. — *Seth Shostak, SETI Institute*

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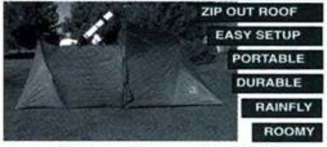

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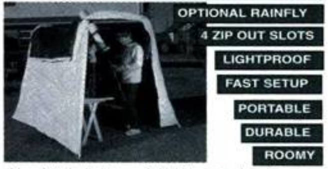

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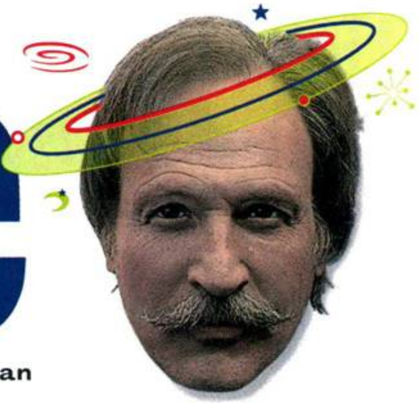

by Bob Berman

Only the Shadow Knows

February 2 is Groundhog Day, the most bizarre of our national holidays. Extraterrestrials, arriving some February to study our customs, might have their heart-units warmed by Valentine's Day, when we give our lovers chocolate to fatten them up. Later in the month, President's Day would help Plutonians understand the "Faces on Earth" they've viewed telescopically — including those odd South Dakota mountains their experts insist are natural formations. But Groundhog Day?

Let's see if they can get this right. Woodchucks emerge from holes and then, despite having IQs of 0.7, examine shadows cast by the nearest star. If they do see shadows, they suffer panic and dive back into the ground. This indicates that Earth's Northern Hemisphere will experience six more weeks of winter. In recent years, this somewhat implausible scenario has revolved around the perceptions of a single Pennsylvania groundhog that serves as the entire country's spokes-rodent.

Aside from the underfunded science of woodchuck anxieties, there's the suspicion that the whole thing is rigged. Six more weeks of winter? Surprise: there's always that much more winter. Since the vernal equinox forever falls six weeks after Groundhog Day (okay, 6½ weeks), spring's onset reliably occurs that much later whether rodents are anxiety-ridden or depressed.

In case you wondered, this actually connects with astronomy, since Groundhog Day is neither arbitrary nor unrelated to the cosmos. February 2 is home to a surprisingly ancient custom, originally Candlemas, the 40th day of Christmas, one of the year's four "cross quarter" days that are exactly centered in the seasons. It's the time midway between the winter solstice and the vernal equinox. (Traditionally, that is; the precise midpoint has now shifted a couple days forward, to February 4). For observers, it's when sunrise classically occurred at the place on the horizon halfway between its annual southernmost extreme and due east — one of those charming Stonehenge-type milestones.

The Groundhog challenge is also "rigged" by being held in February, one of the cloudiest months in the U.S., according to long-term averages. As backyard astronomers lament, the odds of seeing the sun are lowest now, along with the chance of a groundhog seeing his shadow. Moreover, as eclipse chasers are well aware, the sun is far less likely to be visible when it's low because clouds near the skyline are viewed horizontally and tend to "fill in" intervening clear spaces. Because the early February sun never rises very high even at noontime, the deck is stacked against any shadow-viewing outcome. Yet this hopeful prospect of averting a long winter winds up being a sadistic tease for most of us, who live in regions that will have their next early spring when Earth's axis points to Deneb in the year 13,000.

Since February 2 is when people think about shadows, this first Groundhog Day of the new millennium — let's call it G2K — is a particularly good time to explore the subject. For, in all the universe, only three celestial objects ever create shadows on Earth, and they're all out this February 2.

After the sun sets, the sky immediately displays the moon and the third, lesser-known shadow maker, Venus. Except for the kind of extraordinary supernova not seen for centuries, nothing else reaches the magnitude –4 threshold capability to cast naked-eye shadows. Venus does, this month and next, and its shadows are fascinating.

Indeed, the entire topic is more intriguing than one would imagine, because shadows contain surprising amounts of information. Almost anytime you block out a piece of the images scrambled on the ground all around us, you gain knowledge about the light source.

I remember being tormented as a youngster by puzzling sun-shadow characteristics. Why were the shadow-edges of distant trees and buildings blurry, while the shadows of my ankles sharp? Only later did I finally realize that the qualities of a shadow depend on the size of *the light source and the* distance to the surface upon which the shadow is cast. Point sources like Venus get quickly and totally obliterated by an obstruction, so its shadows have sharp boundaries. See this for yourself if you can get away from all artificial lights as well as moonlight, later in February. Looking behind you onto a white surface such as snow, you'll be amazed at how different Venus-shadows appear when compared with the fuzzy outlines of sun or moon shadows — blurry because their edges are where the light source is partially blocked.

By day, you can scrunch your fingers to make a small opening and create a pinhole camera to project the sun's image on the ground. If cast onto a surface perpendicular to the sun, the "hole" in your hand's shadow assumes a perfectly circular outline, proving it's the sun's actual image rather than merely a projection of the irregular aperture created in your hand. Position this solar image so that it lies among blurry shadows of distant branches, and you'll create razor sharp photographs of those distant objects, projected upside down as if by an actual camera lens. It's fascinating, though you may have explaining to do if neighbors happen to be watching.

Moon shadows, for their part, look unexceptional; their familiarity arises because they display exactly the same properties as sun shadows, since both disks are the same size.

This is why Venus-shadows are worth seeking out; their starkness more than their faintness makes them unlike any other natural phenomenon — truly alien.

With winter likely to run its full course, we'll at least have "shadow play" to help pass the time. Could uncovering shadow secrets, this intriguing link between Earth and sky, be the hidden promise of Groundhog Day? Maybe they're onto something, those woodchucks.

Bob Berman's Strange Universe column is a new monthly feature in Astronomy *magazine. Berman is the author of several books on astronomy, including* Secrets of the Night Sky: The Most Amazing things in the Universe You Can See with the Naked Eye.

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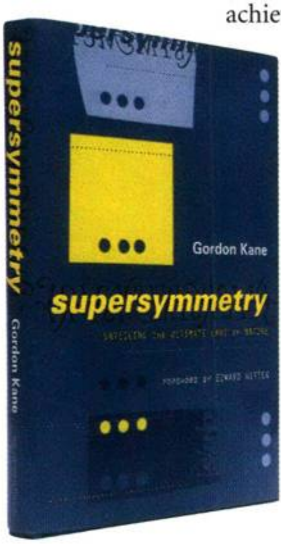
A BOOKS

Supersymmetry: Unveiling the Ultimate Laws of Nature

Gordon Kane, 224 pages, Perseus Publishing, Cambridge, Mass., 2000; ISBN 0-738-20203-7; hardcover, $26.



▶ Kane's discussion of supersymmetry reminds me of what could be an updated version of one of Richard Feynman's classic lectures. Instead of "There is Plenty of Room at the Bottom," a 1959 talk by the late Nobel-Prize winning physicist, Kane has written what could be titled, "There Is Probably Even More Room at the Bottom."

Decades before Intel and Pentium chips, Feynman argued that there was no practical reason that we couldn't make computers several orders of magnitude smaller and more complex. "If they had millions of times as many elements, they could make judgments. They would have time to calculate what is the best way to make the calculation that they are about to make," the master lectured.

In *Supersymmetry*, Kane explains how the accepted but possibly incomplete theoretical framework for describing the origin of the universe and other processes — the so-called Standard Model — might be extended. "Qualitatively, the Supersymmetric Standard Model should become the effective theory at distances of 10^{-17} to 10^{-18} meter, and it should remain the effective theory down to nearly the Planck scale [10^{-35} meter]. It has special properties that allow it to cover that large range, rather than breaking down at shorter distances as most effective theories do."

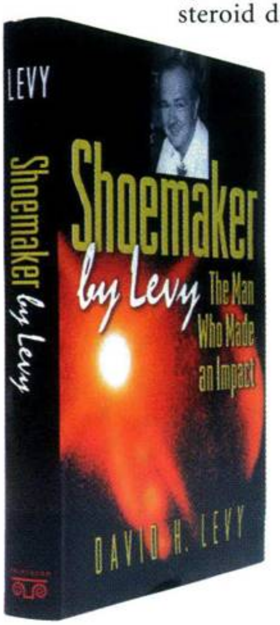
Feynman knew 40 years ago that atoms behave in fundamentally different ways than might be expected because they satisfy the laws of quantum mechanics. In the simplest language available to him, Kane, a particle physicist at the University of Michigan, sets the stage in his book for understanding experiments currently being planned to test the supersymmetry theory. If each of the fundamental particles of nature indeed has a "superpartner," as the theory predicts, then they can be detected at the energies achievable in the world's most powerful particle accelerators — possibly within a few years.

If Kane and his colleagues are right, they may help solve the most basic unsolved problems in physics and explain the biggest mysteries in cosmology in the process. This book is an extremely helpful tool for the educated non-scientist who wants to understand the significance of the particle-accelerator experiments when researchers complete them. — *Rex Graham, senior editor*

Shoemaker by Levy: The Man Who Made an Impact

David H. Levy, 303 pages, Princeton University Press, Princeton, N.J., 2000; ISBN 0-691-00225-8; hardcover, $27.95.

▶ *Shoemaker by Levy* helps explain why it is so much more meaningful to talk about Comet Shoemaker-Levy 9 instead of using its technical name D/1993 F2. (The "D" stands for defunct.) That's because the husband and wife team of Eugene and Carolyn Shoemaker and amateur astronomer David Levy are associated with one of the most remarkable astronomical events ever witnessed: the collision of Comet Shoemaker-Levy 9 with Jupiter in 1994. Their discovery of the comet caused more telescopes to point at the same direction in the sky for one specific event than at any other time in history. Observers were richly rewarded.



In this title-cum-byline, science writer Levy tells the story of his friend and colleague, the late Eugene Shoemaker. Readers learn that as a boy, Shoemaker was obsessed with rocks and the moon, perhaps as early as age 7. His interest was piqued by a set of marbles given to him by his mother that once belonged to his grandfather. The collection included some specimens of agate. It turned Shoemaker into a passionate rock collector. While in high school, he worked as an apprentice lapidary, which led to a major in geology at Caltech during World War II.

Shoemaker's direct lunar curiosity began in the spring of 1948, when he turned 20. He later recalled, as Levy quotes, "I want to go there! I want to be one of the first people on the moon. Why will we go to the moon? To explore it, of course! And who is the best person to do that? A geologist, of course!"

The book traces Shoemaker's path through geological studies of Meteor Crater in Arizona (which he proved was of astronomical origin) to his intuitive drawing of a geologic map of the moon based on old Mount Wilson Observatory photographs. Shoemaker established a team to study astrogeology at the U.S. Geological Survey's Menlo Park office near San Francisco, California, in 1960. A few years later, the USGS launched a full Geological Survey branch for astrogeology in Flagstaff, Arizona, where the Shoemaker family soon transplanted itself. The branch continues to be of major importance in the exploration and mapping of the solar system.

One of Shoemaker's great disappointments in life came with his diagnosis in 1963 of Addison's disease, a steroid deficiency characterized by weakness, weight loss, and other symptoms. It disqualified him from becoming an astronaut. Instead, he turned to how others could best explore Earth's satellite. That same year, he became involved with Project Surveyor, slated to make soft landings on the moon.

Shoemaker advocated the training of Apollo astronauts in geology, and he also instructed them in the subject. Harrison Schmitt was the only Ph.D. geologist to land on the moon. Shoemaker himself

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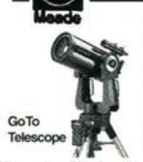

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became so unhappy with the cancellation of the last three Apollo missions that he resigned from the space program.

"Apollo provided outstanding science, but the scientific discovery came from the analysis of the samples brought back, not from the observations of the astronauts," he said. "Why send human beings into space, if not to be prepared for the unexpected?" But while Shoemaker championed potential results from astronauts, he was also quite satisfied to analyze data from the robotic spacecraft (notably the Voyagers) that detected craters around the distant satellites of Jupiter, Saturn, Neptune, and Pluto.

Throughout his excellent adventure in the remote exploration of space, Shoemaker's closest colleague and collaborator was his wife. Together, they eventually discovered some 30 comets. Carolyn was a gifted astronomer in her own right and her record of 32 comet discoveries far surpasses Caroline Herschel's 18th- and 19th-century discoveries of eight comets. It seems unfair that some of the comets were not named "Shoemaker-Shoemaker" by the International Astronomical Union's Central Bureau for Astronomical Telegrams. More recently, the Near Earth Asteroid Rendezvous (NEAR) spacecraft, which is orbiting Eros, was renamed NEAR Shoemaker in honor of the late scientist.

Later in his partly autobiographical book, Levy describes how he joined the Shoemakers at Palomar Mountain Observatory to use the 18-inch Schmidt telescope to search for comets. The personalities of each of the individuals come through. Anyone who reads *Shoemaker by Levy* looking for insights on Gene and Carolyn's relationship will be rewarded. One unfortunate aspect of Shoemaker's personality that we glimpse in a few places in the book is his interaction with his children, which did not always seem amicable.

Shoemaker died of injuries suffered in a 1997 vehicle collision in the Australian outback. The couple went there regularly to study impact craters. The book ends with another collision — of the Lunar Prospector spacecraft intentionally crashed into the moon in 1999. A capsule containing some of Shoemaker's ashes was aboard.

Levy's book should appeal to a wide range of readers, including not only scientists but also those seeking the personalities behind astronomy in the late 20th century. — *Jay M. Pasachoff*

Pasachoff's latest book, The Cosmos: Astronomy in the New Millennium *(Harcourt College Publishing, Philadelphia; 2001), is coauthored by Alex Filippenko.*

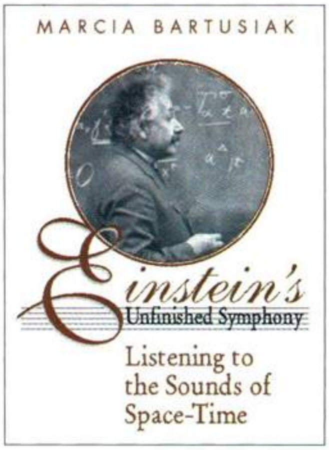
Einstein's Unfinished Symphony: Listening to the Sounds of Space-Time

Marcia Bartusiak, 249 pages, Joseph Henry Press, Washington, D.C., 2000; ISBN 0-309-06987-4; hardcover, $24.95.

▶ Albert Einstein shook the foundations of physics in 1915 with the introduction of his theory of general relativity. In the next 85 years, all but one of its predictions were verified. This final prediction is the existence of gravity waves — ripples in the very fabric of space-time resulting from the movement of an object embedded in it. The detection of gravity waves will open a new window on the workings of the universe.

Einstein's Unfinished Symphony is about the long search for gravitational waves. Veteran science writer Marcia Bartusiak is our guide on an intriguing scientific quest spanning nearly a century. Much more than a museum tour, this is the story of passionate, intelligent individuals who yearn for a deeper understanding of the universe.

The story ostensibly begins in 1915 with Einstein. However, to appreciate how truly revolutionary his ideas were, Bartusiak takes us back much further in time. She traces the development of our ideas of space and time from the early Greek philosopher-scientists to the absolute space and time of Isaac Newton. We learn how 18th-century mathematicians experimented with multidimensional geometries, as opposed to the three-dimensional Euclidean geometry we all learned in school. We discover that Bernhard Riemann generalized the geometry of curved space to four, five, and even higher dimensions — laying the groundwork for Einstein's universe consisting of three spatial dimensions with a fourth dimension of time.



According to 18th-century physics, light waves require a medium through which they can be transmitted. Many 19th-century physicists searched for this medium, dubbed the cosmic "ether." Enter a "cocky kid with mediocre college grades and no academic prospects, but an unshakable faith in his own abilities." While working as a patent clerk, Einstein developed his special theory of relativity, in which he proposes that light propagates in empty space with a speed, "c," which is constant and independent of the motion of the source. Thus begins the Einstein revolution.

After we are clear on the theory of relativity and all its implications, Bartusiak delves into gravitational radiation, or gravity waves. These waves move at the speed of light and are produced when masses move about. The strength of a gravitational wave depends on the amount of mass and the nature of its movement, but, in general, all gravitational waves are expected to be incredibly weak. The frequency of the typical gravitational wave would lie in the audio range. Detection of gravitational waves requires scientists to push the "technological envelope." Why bother? Gravitational waves, unlike electromagnetic waves, interact very little with matter. Once detected, they will yield information about supernovae, black holes, neutron stars, and even the early universe that is not available by other means. Bartusiak discusses the difficulties of detecting gravitational waves in great detail.

Einstein's Unfinished Symphony does not just praise of the genius of one man. Bartusiak points out that many are involved in the scientific endeavor; even Einstein himself drew on the work of scientists such as Bernhard Riemann and he collaborated with other scientists including mathematician Hermann Minkowski. The search for gravitational waves spans nearly a century and has involved many theoretical and experimental physicists.

Bartusiak's lively style illuminates the contributions of physicists; however, the chapters on detectors are bogged down with details too burdensome for the average reader. The final chapter picks up speed and leaves the reader rooting for scientists around the world who wait eagerly and patiently for the universe to play them a tune.
— *Jennifer Birriel, Carleton College* ■

The Webweaver Picks

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Kids Astronomy
This attractive, easy-to-use site introduces astronomy to children in kindergarten through 8th grade and provides lesson plans for teachers of those grades: http://www.kidsastronomy.com/

Venus
The planet puts on a great show this month. This website offers more about the "evening star": http://nssdc.gsfc.nasa.gov/planetary/planets/venuspage.html

Orion Nebula
If you missed the latest astronomy.com quiz question about M42, this homework is enjoyable: http://seds.lpl.arizona.edu/messier/m/m042.html

2001: A Space Odyssey
Stanley Kubrick's 1968 sci-fi film classic depicted a world in which mankind ventured into deep space in amazing vehicles. Okay, he was wrong. But we love these space-vehicle models: http://www.strafe.com/2001/

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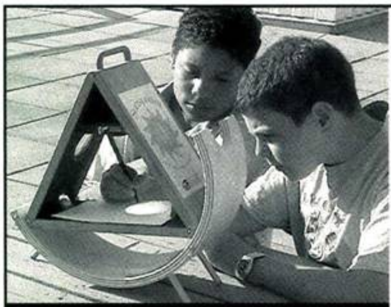

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Winter Star Party. Sounding like an oxymoron to the uninitiated, to serious observers the world over, these words conjure up images of Florida's white sand beaches, palm trees, and clear, dark skies, along with visions of Omega Centauri, Eta Carinae, and the Southern Cross. This year's **Winter Star Party** is taking place **February 19–25** at Camp Wesumkee on Florida's West Summerland Key. The Southern Cross Astronomical Society sponsors this annual event, one of the largest in the United States. Advance registration is required. For more information, contact registrars Fred & Lucille Heinrich, 6165 Wiggins Road, Live Oak, FL 32060; (904) 362–5995; fax, (904) 362–5996; e-mail, Heinrich@atlantic.net; website, http://www.scas.org. For information about accommodations call (800) FLA–KEYS.

Michael Klensch

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JANUARY 22

Hayden Planetarium Lecture

New York, New York. **David Helfand, Chandra: The X-ray Universe Revealed.** For more information, contact the Hayden Planetarium at (212) 769–5900; website, http://www.amnh.org/education/hayden.html.

JANUARY 23

Dean Lecture Series — The Blind Leading the Seers: Science Fiction and Science

Morrison Planetarium, California Academy of Sciences located in Golden Gate Park, San Francisco, California. 7:30 P.M. Tickets are $3; purchase in advance of lecture recommended. Website, http://www.calacademy.org/planetarium/.

JANUARY 27, FEBRUARY 16

Adler Astronomy Lectures

Adler Planetarium and Astronomy Museum, Chicago, Illinois. **January 27, Alexander Wolszczan, "Beyond Our Solar System: Discovery of Pulsar Planets"** in conjunction with the exhibit **"The Remarkable Work of Copernicus, Hevelius, and Other Historic Polish Astronomers,"** on display **through January 28. Rocky Kolb** of the Fermi National Accelerator Lab and the University of Chicago will present **"Primordial Soup: A Little Taste of the Big Bang," February 16.** For more information, contact (312) 922–STAR; or view their website, http://www.adlerplanetarium.org.

FEBRUARY 21–25

Orange Blossom Special Star Party

Hickory Hill Observing Compound, near Brooksville, Florida. Sponsored by the St. Petersburg Astronomy Club. Contact Dennis or Ellen Farr, 8811 W. Broad Street, Tampa, FL 33615; (813) 884–9111; e-mail, DneFarr@aol.com.

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Kisatchie National Forest, central Louisiana. Sponsored by the Baton Rouge Astronomical Society. For more information, contact Don Weinell, 1605 South Park Avenue, Gonzales, LA 70737; e-mail, weinell@eatel.net; website, www.eatel.net/~weinell.

MARCH 23–26

South Pacific Star Party

Wiruna, near Ilford, NSW, Australia. Hosted by the Astronomical Society of New South Wales, this is the largest amateur astronomy event of its kind in Australia. For more information, contact Les Sara, e-mail, Secretary@asnsw.com; website, http://www.asnsw.com.

MARCH 31

Queensland Astronomy Education Conference

Queensland, Australia. Biannual educators' conference targets the teaching of astronomy and astronautics in primary and secondary schools. Program includes portable planetarium sessions, lectures, workshops, and nighttime observing. Contact Paul Floyd, e-mail, ssemps@ozemail.com.au; website, http://www.ozemail.com.au/~ssemps/confer/index.html.

APRIL 20–22

Spring Central Texas Star Party

Canyon of the Eagles Lodge and Nature Park near Burnet, Texas. For information and reservations at the park hotel, call (800) 977–0081 or check online at http://www.canyonoftheeagles.com. For more information, contact the Austin Astronomical Society, P.O. Box 12831, Austin, TX 78711-2831; (512) 252–2966; e-mail, anne@hadkins.com; website, http://www.main.org/aas/activity.html#centex.

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CONTACT

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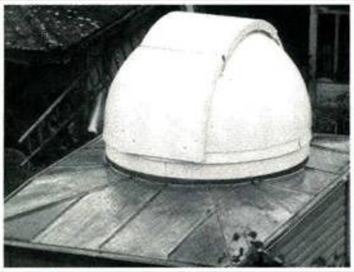

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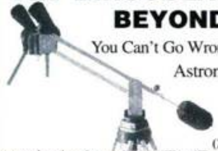

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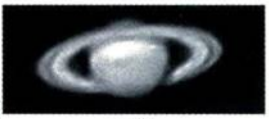

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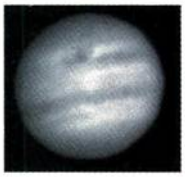

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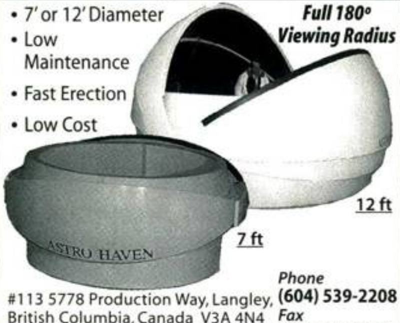

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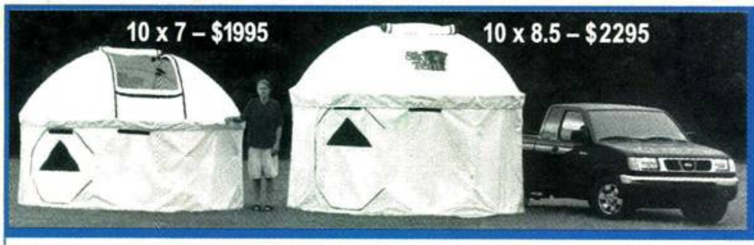

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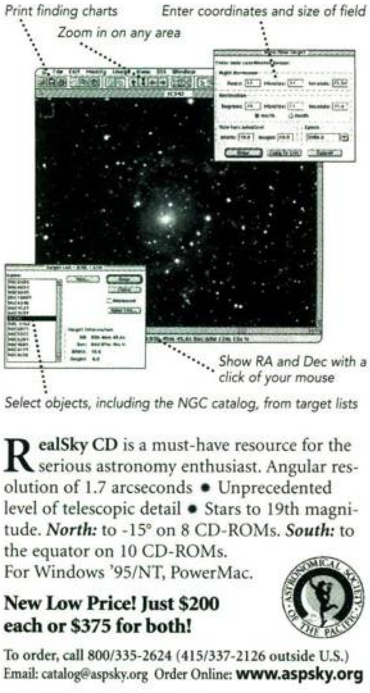
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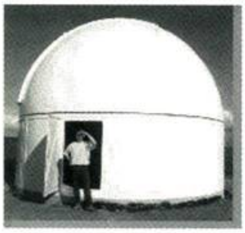

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WORLDS IN TRANSIT

Searching for subtle dips in brightness is all the rage among astronomers seeking planets beyond the solar system.

HUNTING METEORITES

The June 1998 blasts that ripped the air above a parched New Mexico landscape set off a frenzy among amateur and professional meteorite hunters.

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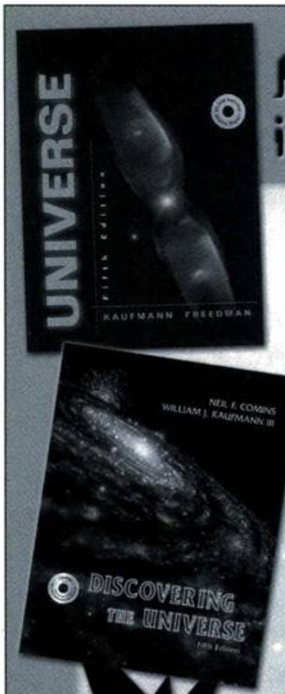

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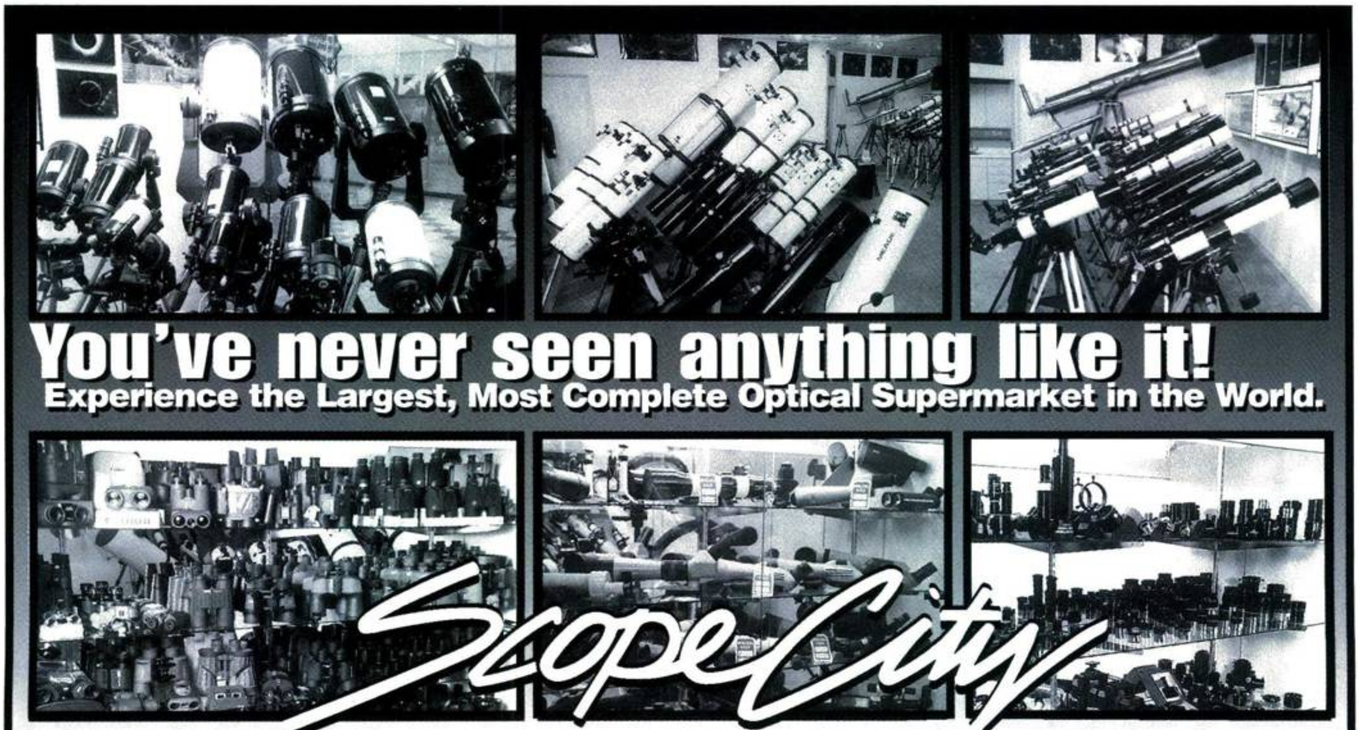

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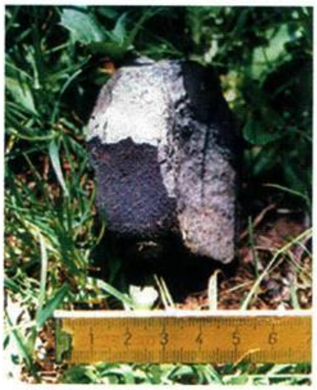
METEORITE

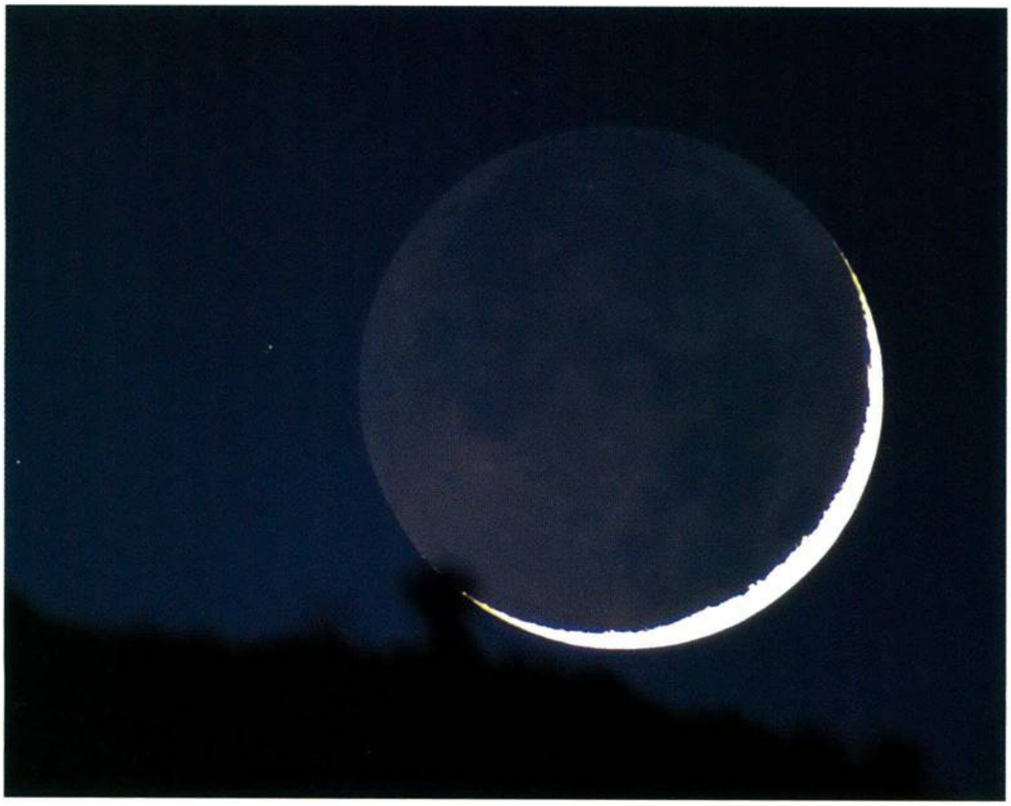
The "Beskydy" Bolide

A bright meteor lit up daytime skies last May and dropped fragments over Eastern Europe.

▶ On May 6, 2000, just before 2 P.M. Central European Daylight Saving Time, a very bright daytime bolide soared over the Czech Republic, Poland, and Slovakia. The bolide was comparable to the sun in brightness. The final portion of its passage through Earth's atmosphere was accompanied by a huge explosion audible within a distance of more than 50 kilometers (30 miles) from the fireball trajectory.

Two major observatories operate in the region: The Observatory and Planetarium of Nicholas Copernicus in Brno and the Observatory and Planetarium of the VSB-Technical University of Ostrava. Staff members working on May 6 recorded dozens of reports relating to this unusual phenomenon. Because visual observations are not accurate enough to determine an exact





Moonset (above)

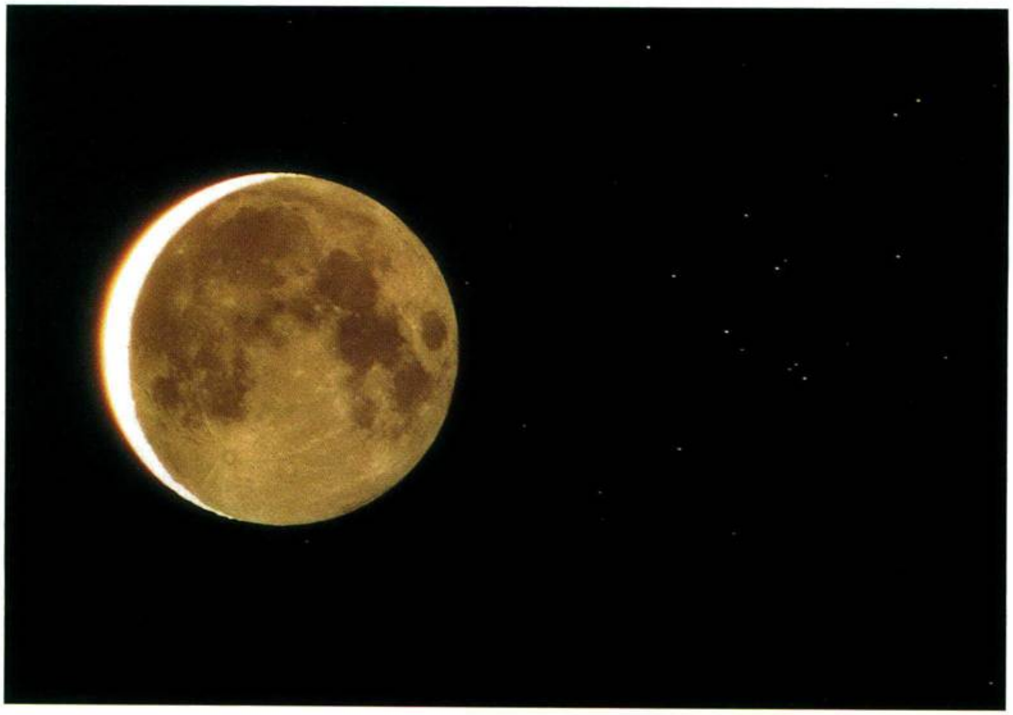
STEPHEN PITT

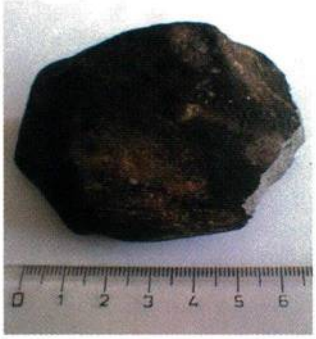
(6-inch f/8 refractor, Fuji Provia F100 film, taken June 1, 2000, from Joshua Tree National Park)

Crescent Moon and the Beehive (M44) (below)

ALBERT STEELHAMMER

(4.7-inch f/8.3 refractor, Kodak Royal Gold 200 film, 30-second exposure taken 5:30 A.M. CDT on August 27, 2000)

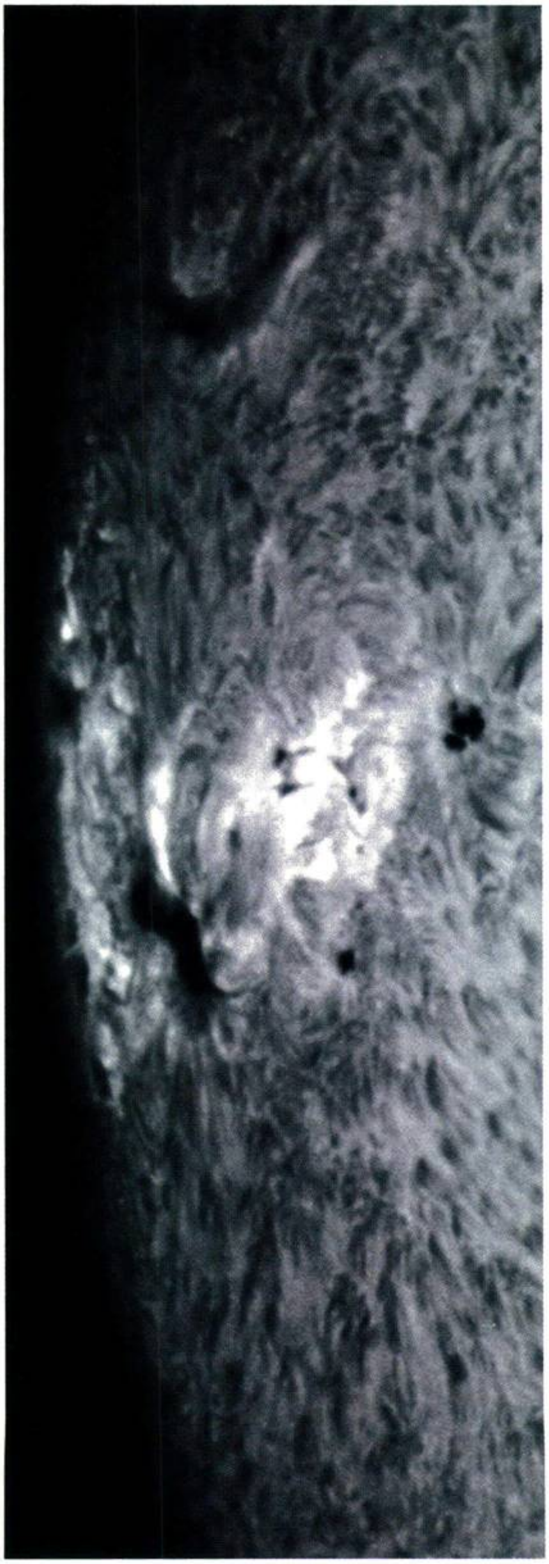




atmospheric trajectory, astronomers hoped that at least two people might have photographed the bolide. And indeed some had. Three people called to say that they had captured the dazzling display using video cameras. As a result, the bolide's path could be determined. This is only the fifth time in history that a meteor's precise trajectory could be calculated.

In the Czech Republic, only one professional institution deals with meteors: the Department of Interplanetary Matter at the Astronomical Institute of the Academy of Science in Ondrejov. Its two specialists, Jiri Borovicka and Pavel Spurny, traveled to the Observatory and Planetarium in Ostrava where a recovered meteorite from the May 6 incident was in residence. The scientists met the meteorite discoverer and borrowed the space rock, which weighed 214.2 grams, for scientific investigation. A 1-gram specimen was sliced from the meteorite for an analysis carried out by Petr Jakes of Charles University in Prague. He identified the meteorite as an ordinary chondrite (classification H6) with unusually small chondrules.

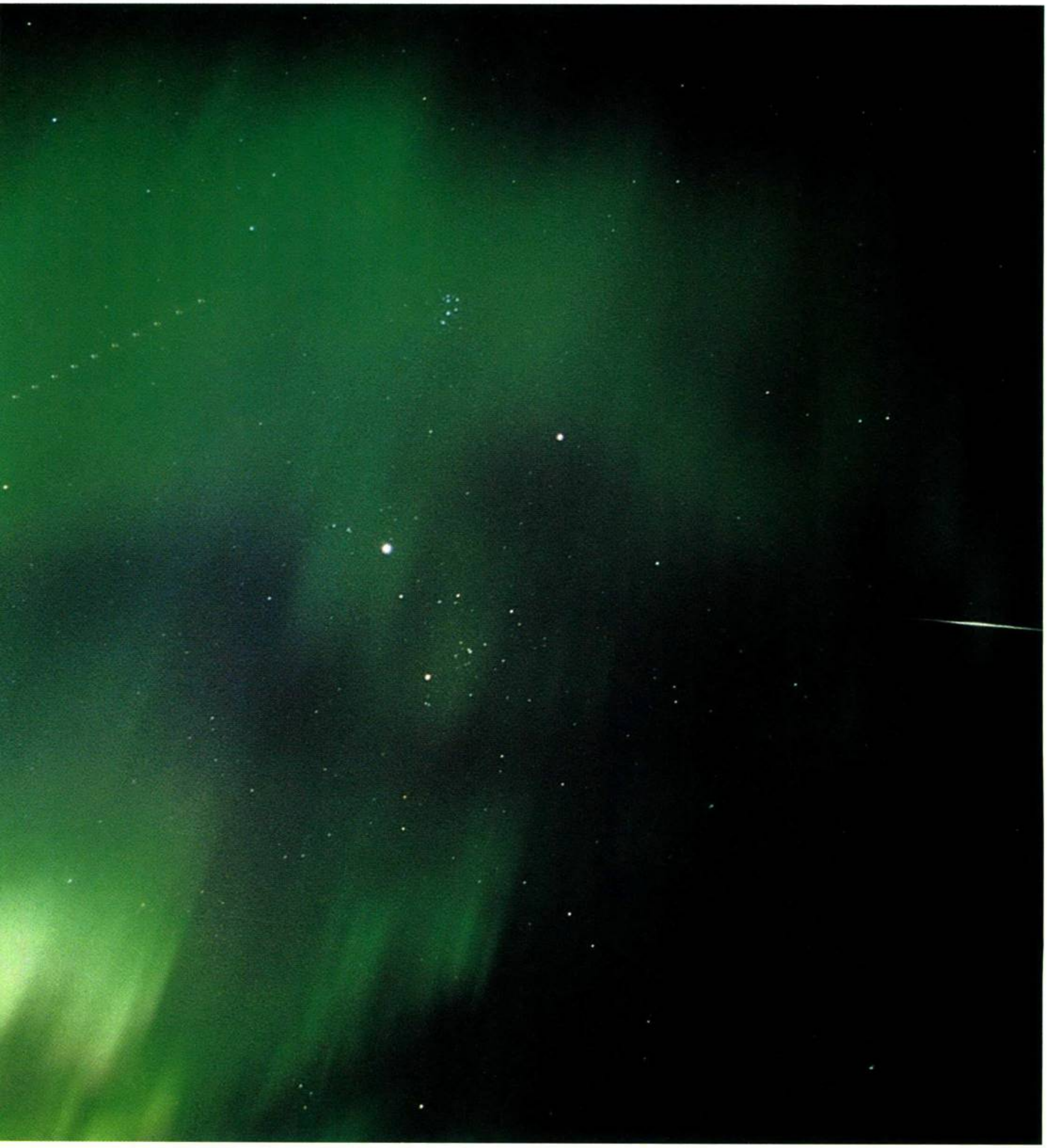
Three weeks later, on May 25, someone telephoned in a report of another meteorite being found. Weighing 329.5 grams, it was located 3 kilo-



Sunspot Group 9169

DAVE MOGENSEN

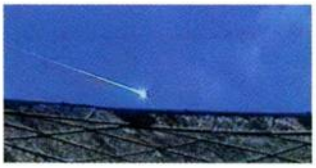
(6-inch refractor at f/30, Daystar H-α filter, Kodak Tech Pan film, 1/15-second exposure taken 12:00 P.M. CDT on September 18, 2000)



Aurora, Airplane Trail, Jupiter, Saturn, Pleiades, Hyades, and Iridium Flare

DANIEL TARDIF

(28mm lens at f/2.8, Fuji Superia 400 film, 25-second exposure taken between August 11 and 12, 2000, from St-Nérée, Quebec)



meters from the site of the first fragment. Again, a sample weighing about 1 gram was separated and analyzed at Charles University in Prague. Both fragments, after delivery to specialized laboratories in the Apennines, Italy, had their radioactive properties measured. The results should be known several months from now. (Overall, more than 20 pieces of the Beskydy meteorite were recovered.)

In the Ostrava region, over which the bolide streaked, a very dense seismic network exists. The readings from the seismic monitoring stations are being used for an analysis of the sounds generated by the bolide.

The name of the Beskydy Bolide comes from the mountain range situated in the eastern part of the Czech Republic in northern Moravia. Poland borders the region to the north and the Slovak Republic is just east. The Beskydy Mountains run north-south and are covered with forests and pastures. ■

Tomas Graf, Tomas Havlik, and Jiri Holusa work at the Observatory and Planetarium VSB-Technical University in Ostrava, the Czech Republic.

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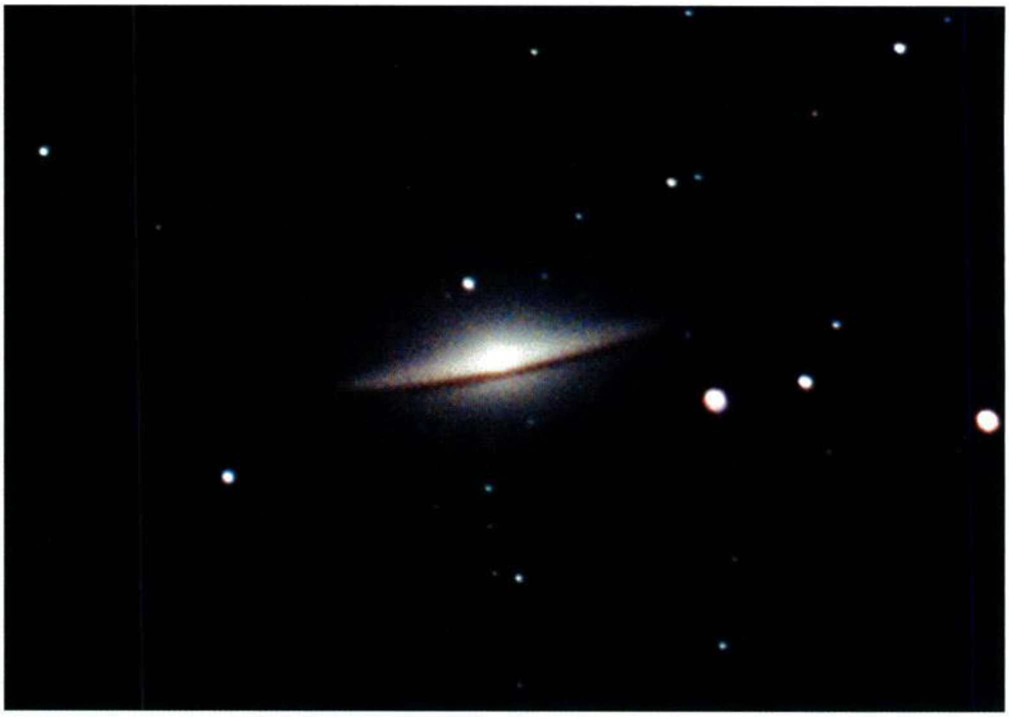
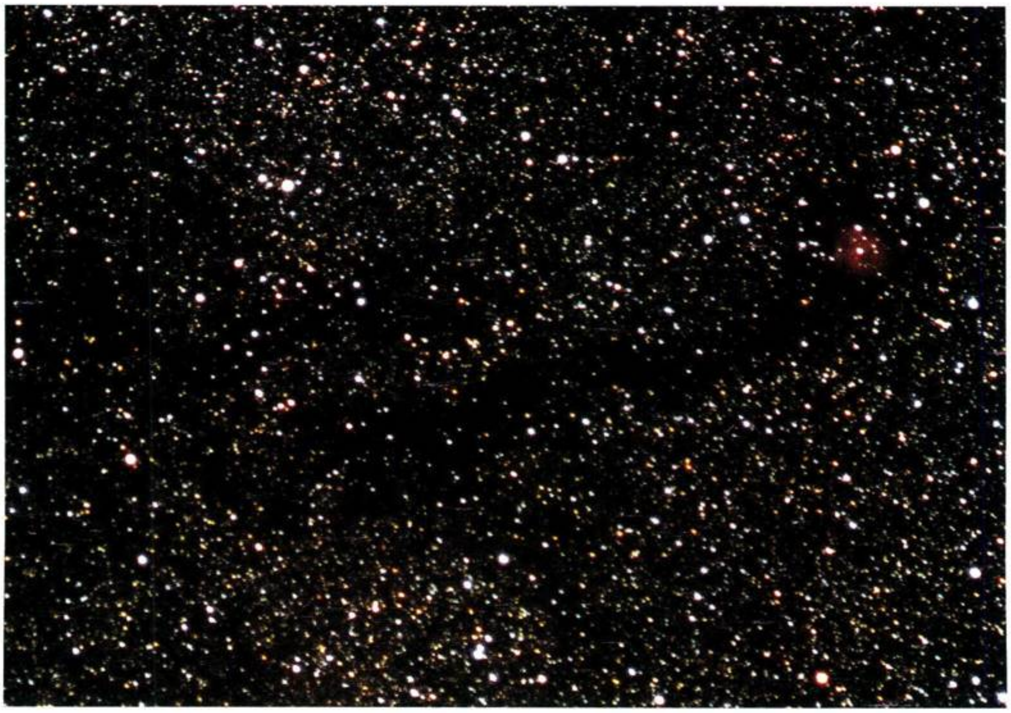


The Sombrero Galaxy, M104

ANTHONY PILATO

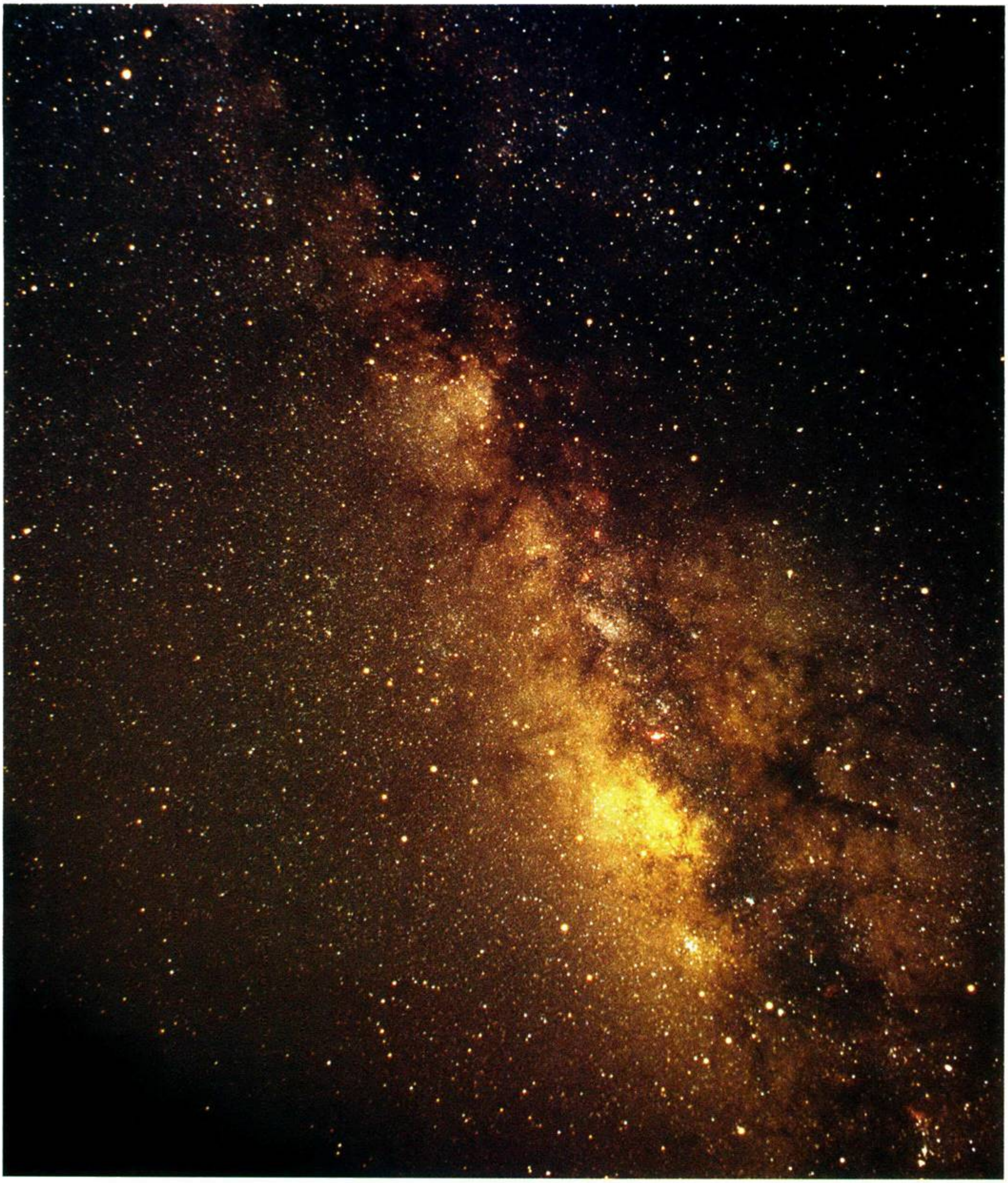
(11-inch SCT at f/7.5, Kodak Pro 400 PJ film, composite of two 90-minute exposures)



The Cocoon Nebula, B168, and M39

ANTHONY GALVÁN III

(300mm lens at f/2.8, Fujicolor 800 film, 40-minute exposure)

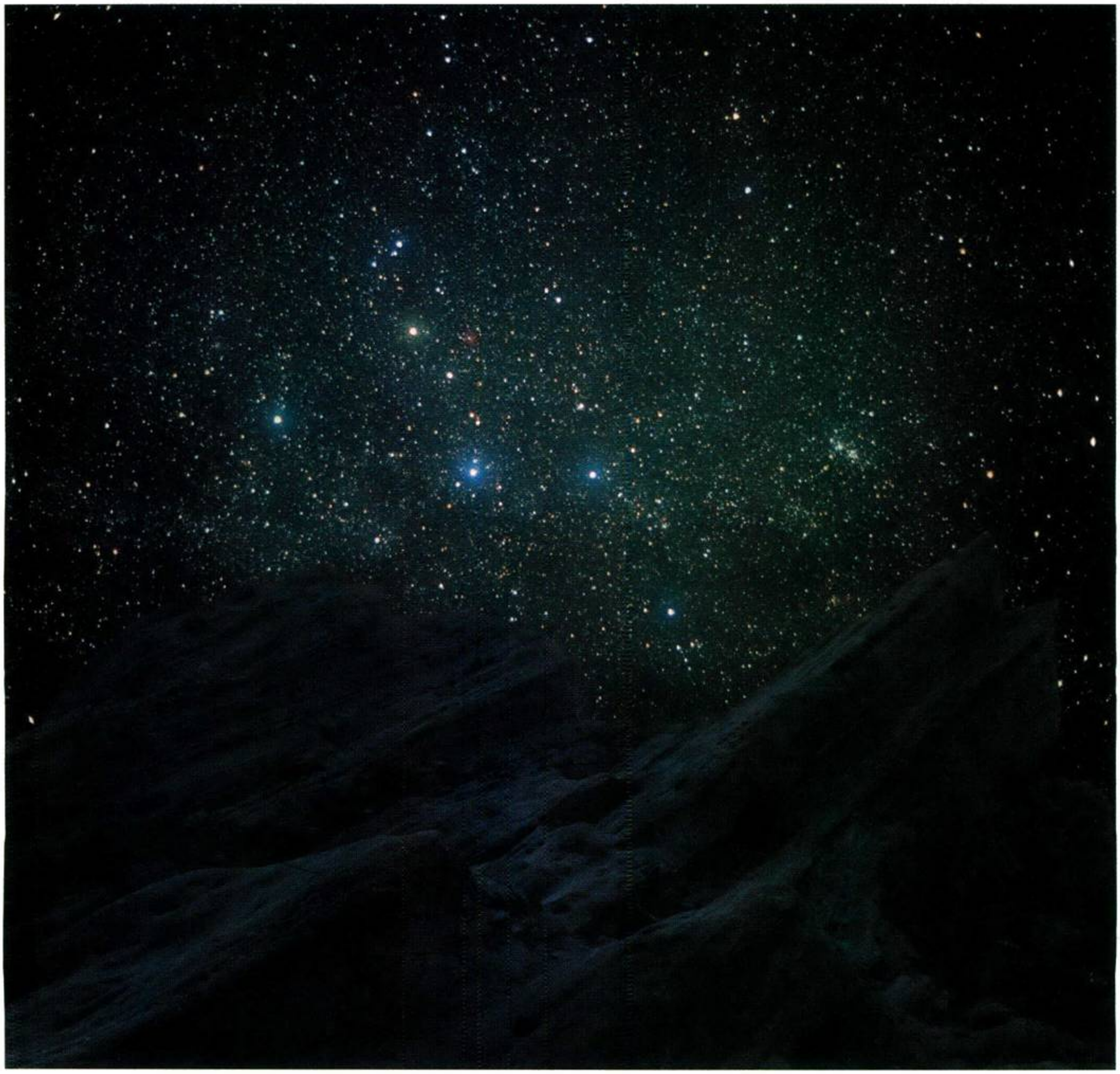


Milky Way

STERGOS MANOLAKAS AND STRATOS KOUFOS

(19mm lens at f/3.5, Kodak GPY 400 ISO film, 30-minute exposure)

This month's best astrophoto



Cassiopeia over Vasquez Rocks State Park

VAL VILLALOBOS

(200mm lens at f/4.5, Kodak PPF 400 film, composite of a 10-minute exposure with a diffuser for the stars and 5-second exposure on Kodak 200 film of Vasquez Rocks at Vasquez Rocks State Park, California)

The 2nd-magnitude yellow star, Schedar (Alpha Cassiopeiae), stands out from its blue neighbors and is one of the brightest stars in the northern polar sky. The Double Cluster in Perseus (NGC 869 and 884) appears at right.

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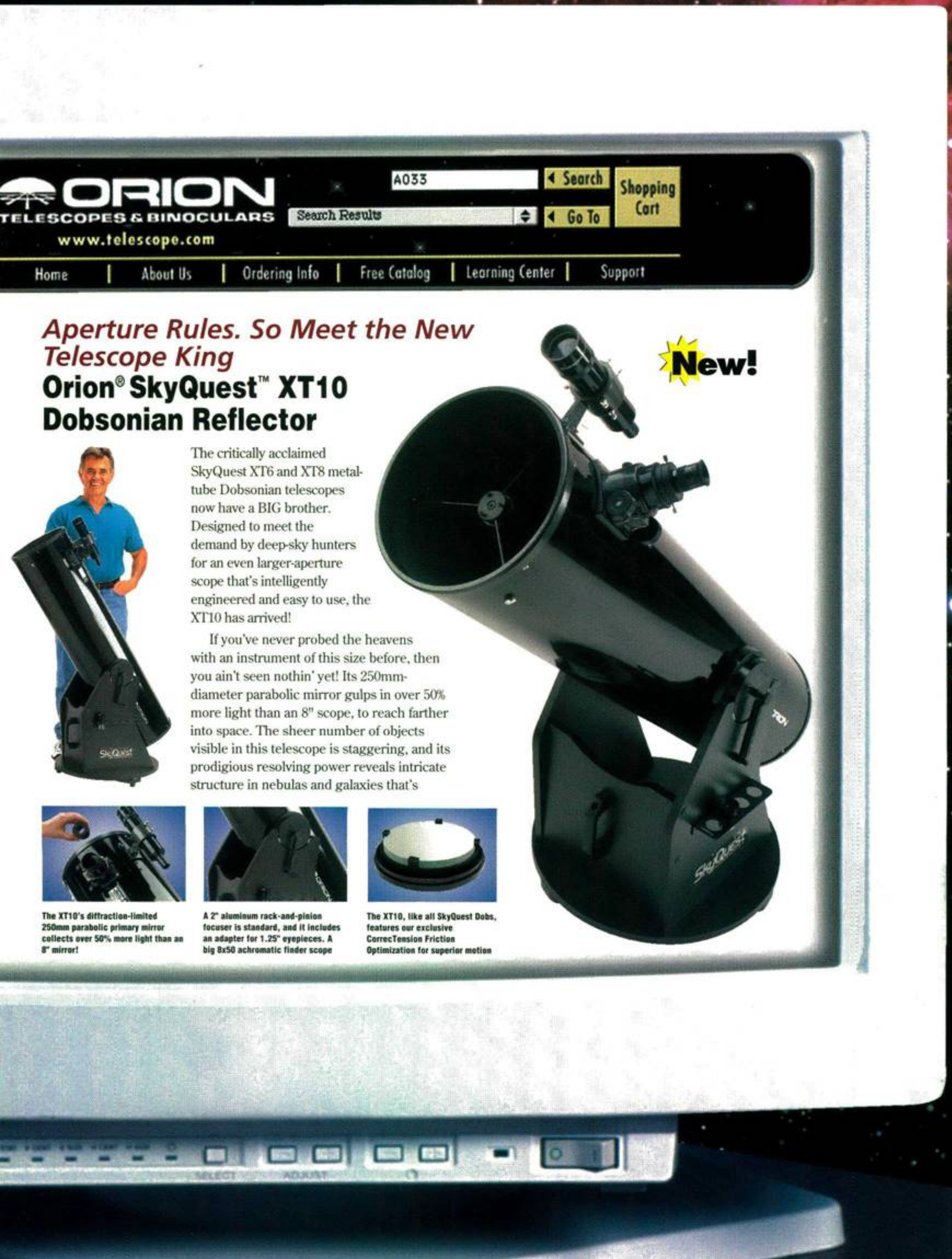
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If you've never probed the heavens with an instrument of this size before, then you ain't seen nothin' yet! Its 250mm-diameter parabolic mirror gulps in over 50% more light than an 8" scope, to reach farther into space. The sheer number of objects visible in this telescope is staggering, and its prodigious resolving power reveals intricate structure in nebulas and galaxies that's

The XT10's diffraction-limited 250mm parabolic primary mirror collects over 50% more light than an 8" mirror!

A 2" aluminum rack-and-pinion focuser is standard, and it includes an adapter for 1.25" eyepieces. A big 8x50 achromatic finder scope

The XT10, like all SkyQuest Dobs, features our exclusive CorrecTension Friction Optimization for superior motion

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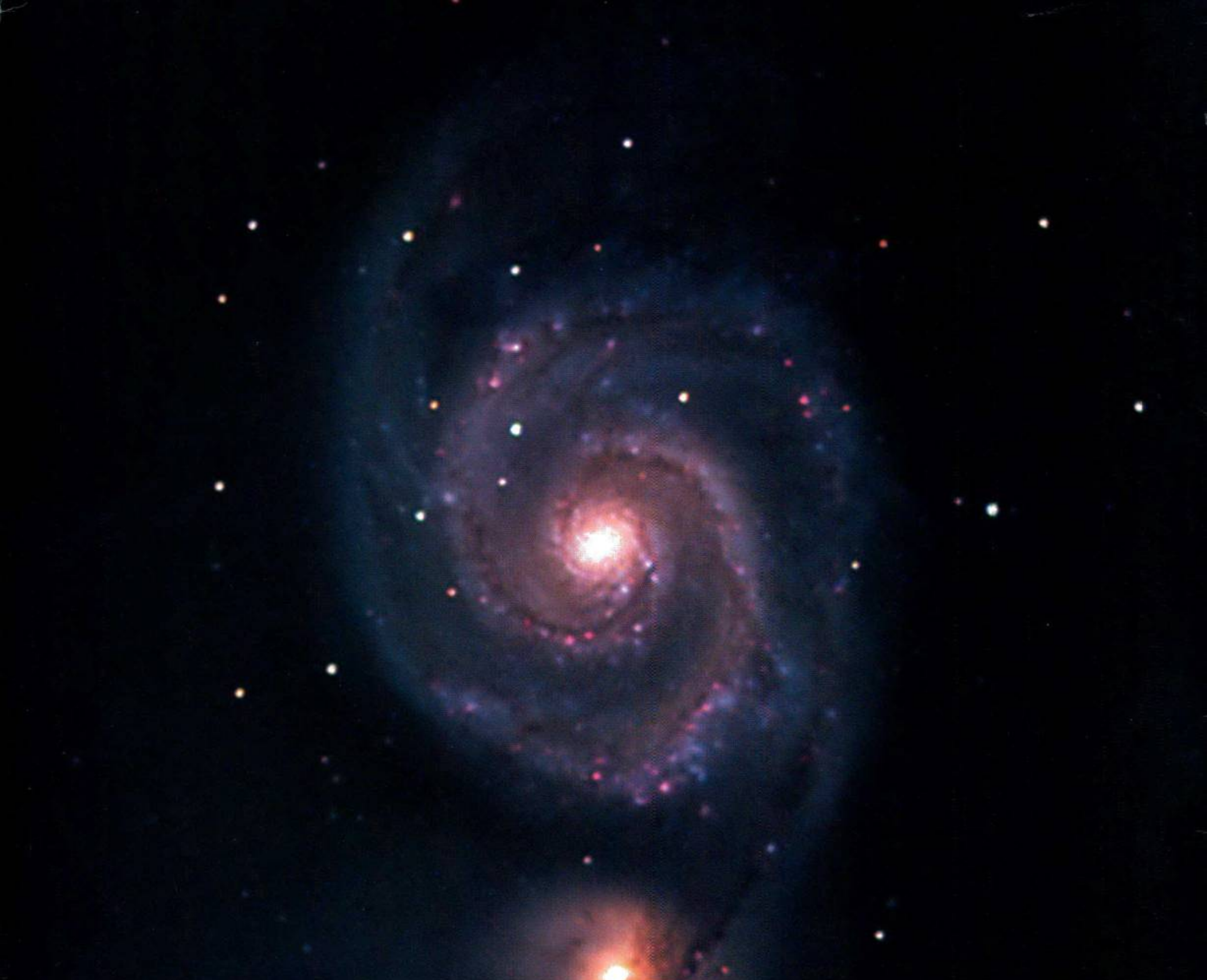

The Whirlpool Galaxy (M51) in Canes Venatici. Imaged by Jack Newton of Chiefland, Florida with the Meade 16" LX200 Schmidt-Cassegrain telescope and Meade Pictor 1616XTE CCD digital camera. This image, another example of Mr. Newton's voluminous and precedent-setting work, defines the galaxy's two primary spiral dust lanes tracing deeply into the 15 arc-second-diameter nucleus. Numerous dark filaments crossing the spiral arms, complexes of star clouds, and star clusters located within the galaxy's structure are also evident.

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